THE CASE AGAINST THE RAIN

A Report on Acidic Precipitation and Ontario Programs for Remedial Action

Ontario

Ministry of the Environment

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This report has been reprinted with some revisions and supplements added to outline major Environment Ontario activities and strategies during 1981-82. Government Regulation requiring Ontario Hydro to reduce emissions, introduced in 1981, is also outlined in a supplement.

The reprinted information is accurate for the period and sources indicated. New data on emission levels and reports on studies now underway concerning the impact of acid rain will be detailed when a new edition of this report is published early in 1983.

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Ontario

Ministry of the Environment

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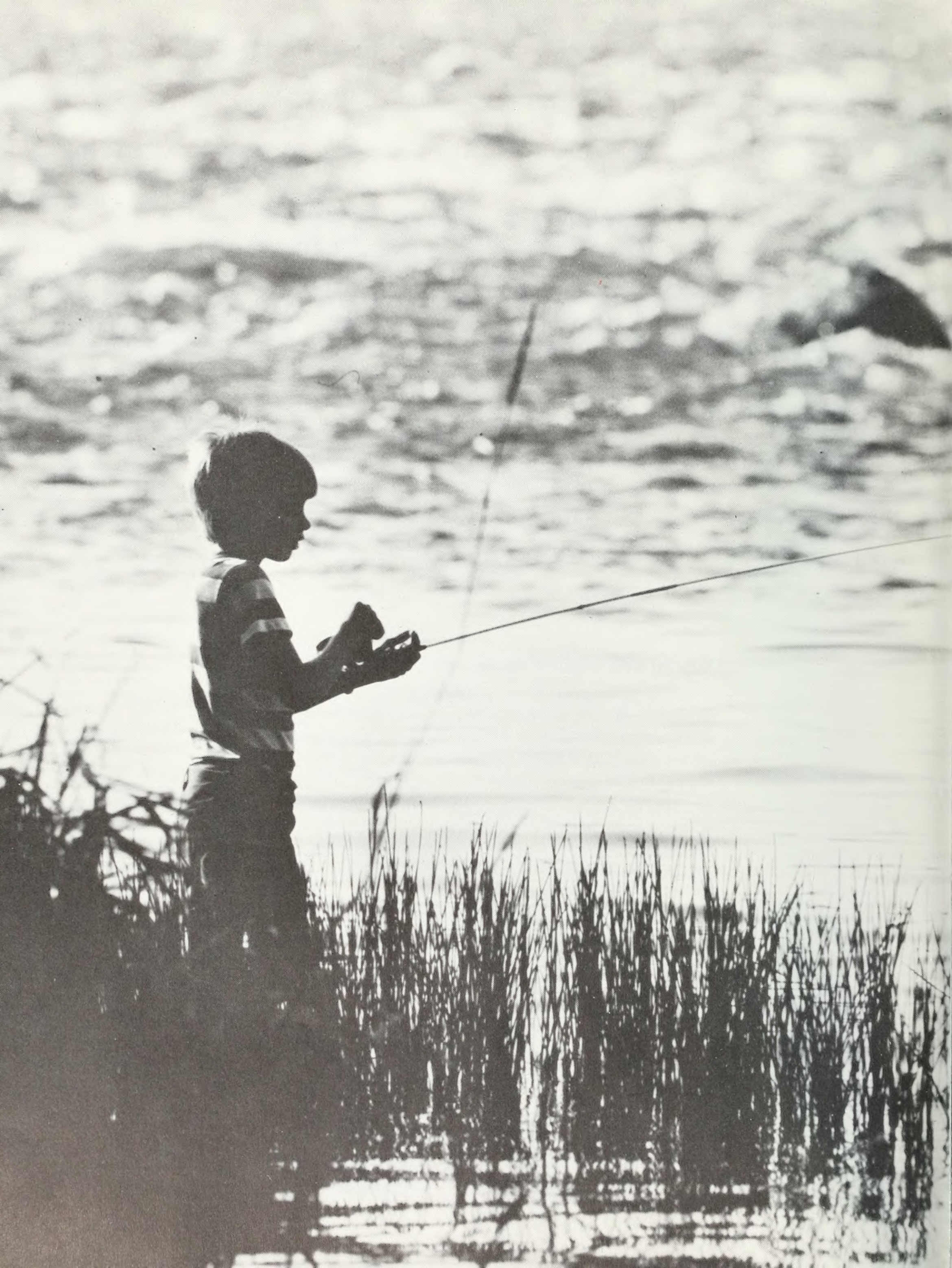

UPDATE:

Environment Ontario's Abatement Activities and Strategies, 1981-82*

. . . One of our major activities is a comprehensive program to cope with the threat of acidic precipitation. Two years ago, the ministry spent just over half a million dollars on this program. In the current fiscal year (1981/82), our ministry proposes to spend $7.0 million on scientific investigation, legal activities and abatement strategies to deal with the long range transport of air pollutants.

These activities have raised public awareness to the point that "Acid Rain" has become a household word. Virtually every branch in my ministry is involved in the complex research effort required to determine sources, deposition, effects, more effective abatement actions and to present our case in the International Forum. I will take a few minutes to outline the ministry's activities in this field.

Monitoring Networks

Two networks of monitoring stations were set up in 1980 to measure wet and dry deposition and to identify sources of acid rain. In 1981, these networks were expanded to include 60 locations. These monitoring stations play a vital role in our ongoing research to determine the quantity, acidic concentrations and effects of acid rain, snow, and dry particulate matter falling throughout the province. . . .

By combining these deposition data with information derived from ministry studies focused mainly on our most sensitive areas — the Muskoka/Haliburton and Sudbury regions — our scientists are able to extrapolate their findings on lake deterioration rates to the entire province. (see text — pg. 8). . . .

The monitoring program also identifies the directions from which the pollution comes from numerous North American sources.

Modelling of LRTAP (Long Range Transport of Air Pollutants)

We are well aware that the long distance transport of sulphur and nitrogen compounds emitted into the atmosphere is closely related to the acidic precipitation phenomenon. Carried over great distances, these emissions frequently can undergo transformation to acidic compounds which are eventually deposited in rain or snow.

The Ministry's Air Resources Branch has developed a mathematical model which is used to estimate total deposition of sulphur throughout the province. The model has been designed to determine the contribution of pollutants to acidity over the sensitive lake areas in Ontario from both Canadian and American sources. Its results have been verified using measured values of sulphur in precipitation obtained from the monitoring networks in both countries.

Effects

My ministry has been studying the effects of acidic deposition on aquatic ecosystems for several years. Most of this work is centred at our research facility at Dorset and has received worldwide attention. The results will assist the ministry in determining appropriate abatement programs.

To date, approximately 3,000 lakes throughout the province have been tested for acid sensitivity. The results of this ongoing survey are being reported regularly to the public. Our first survey report was published last May, and an up-dated summary of acid sensitivity surveys from more than 2,500 of these lakes will be released shortly. . . .

This year, the ministry initiated a joint project with the Ministry of Natural Resources to test the feasilbity of neutralizing lakes by "liming". We firmly believe

Environment Minister Keith Norton and Senator Mel Frederick (right) from Minnesota, member of one of the U.S. delegations that toured Ontario areas affected by acid rain, discuss the problem that worries both jurisdictions. Mr. Norton was appointed Minister of the Environment in April, 1981 following the retirement of Dr. Harry C. Parrott.

**Excerpts from the Hon. Keith C. Norton's statement to The Standing Committee on Resources Development, Ontario Legislature — Ministry Estimates, 1981/82 (December 1, 1981).*

that reduction of emissions at source is the most effective long range program to protect the environment. However, until the effects of long term abatement programs take place, this program will determine the extent to which sensitive lakes can be protected.

Acidic precipitation also has the potential to cause serious and widespread damage to terrestrial ecosystems in areas where the soils and bedrock cannot "buffer" or neutralize the acid. Large areas of Eastern Canada lack this buffering capability and as a result, detrimental effects to soils and vegetation could result. (see text — pg. 21). . .

So far these effects have been largely observed only experimentally. We have not oberved direct damages to crops or forests in Ontario under the currently measured rates of acidic deposition. The circumstantial evidence in other countries, notably Sweden and Germany, suggests that it is only a matter of time before such effects will become apparent.

Last year, more than 1,000 soil samples were collected from 100 stations to provide data on background conditions. Vegetation samples were also collected. Repeat surveys and additional samples are being collected on a regular basis so that trends in terrestrial ecosystem changes can be identified.

Economic Impact

It is readily apparent from this brief description of effects, that many of Ontario's natural resources are at risk, or threatened, from the known and potential effects of acidic deposition. But what does this mean to the eight-and-a-half million residents of this province? These resources are the basis for a significant proportion of Ontario's economy.

Tourism, for example, ranks second only to automobiles and auto parts, as this province's major source of foreign exchange. Aquatic based tourism, which is most vulnerable to the effects of acid rain, generated over a billion dollars in direct and indirect expenditures in 1980 alone. Forestry and agriculture constitute a significant part of Gross Provincial Product. Each of these economic activities generates jobs and income which are important to the province as a whole and represent even greater proportions of the economic base in certain regions. The damage to our waters, soils, forests and wildlife will be felt in economic terms throughout the province if this insidious pollution should persist.

To determine the extent of the potential economic effects, my ministry is undertaking a series of studies. An important objective is to provide procedures for estimating the economic consequences of acidic precipitation as new data and more knowledge about the physical effects become available. . . .

For resources where markets exist, such as forestry and agriculture, the methodology is reasonably straightforward. For activities such as sportsfishing or the desire for a clean and healthy environment, much of the ministry's work is pioneering. These studies will permit us to determine more clearly what we and others will gain by controlling acid rain, and even more important, what we shall be losing if we do not.

Federal/Provincial Co-operation

There is ongoing liaison, co-operation and consultation among my ministry, the federal government, and our sister provinces, on the issue of acid rain.

Since the Memorandum of Intent between Canada and the United States was signed in 1980, this ministry has been a very active participant in the various Work Groups established to examine the problem and to propose various abatement strategies. The data compiled by these groups will form the basis for negotiation towards a bilateral agreement between the two countries to control long range transport of air pollutants.

To achieve this goal, both the federal and provincial governments are pooling resources and research findings and reporting on effects, economic impact and abatement costs and strategies. I am proud to say that Ontario is a major contributor to this project.

Since signing the Memorandum of Intent, several other activities have been undertaken in our efforts to move quickly towards a solution and to maintain momentum.

Legal Initiatives/Interventions in U.S. Courts and Tribunals

In March, 1981, the ministry commenced a series of legal initiatives which involved interventions in proceedings before the United States Courts and the Environmental Protection Agency.

The U.S. Environmental Protection Agency was petitioned by several mid-western states to permit increases in the emission limits of 20 coal burning power plants. Most of these states, located in the Ohio Valley, have been identified as major contributors to the acidic deposition problem in Ontario.

In response to this proposal, the ministry was permitted to present its case in Washington in support of New York and Pennsylvania which also opposed the proposed relaxation in standards.

In its submissions on March 12th and on March 27th, Ontario urged the Environmental Protection Agency to disapprove proposed revisions to State Implementation Plans which would lead to increases in allowable sulphur dioxide emissions. Noting that several of the plants were already exceeding current limits, Ontario also urged EPA to vigorously enforce the existing standards. We urged EPA to make a break with its traditional approach of considering only local effects and individual sources and proposed that EPA evaluate the cumulative effect of the revisions on Ontario and take into account evidence of long range transport.

In making its case, Ontario relied on rights conferred by accords and specifically the Memorandum of Intent which committed the parties to "promote vigorous enforcement of existing laws and regulations . . . in a way which is responsive to the problems of transboundary air pollution". Ontario also relied on general principles of international law established by the decision of the Arbitral Tribunal in the Trail Smelter case in British Columbia during the 1930's. Ontario further took the position that Section 115 of the Clean Air Act dealing with international pollution had been activated by a ruling on January 16, 1981 by the then Administrator of the Environmental Protection Agency, Douglas Costle.

On March 17th, the State of Ohio and two power companies in the State commenced proceedings in the United States Court of Appeals for the District of Columbia to set aside the Costle ruling on which

Ontario relied in support of its legal position. Since EPA regarded the Costle ruling as a press release only and without legal status, Ontario moved to intervene to ensure the ruling was not set aside or its status undermined in the proceedings. Ontario eventually reached an agreement with EPA to the effect that the petitions would be dismissed without the court giving reasons. This agreement was opposed by the power companies involved.

On October 9, 1981, in a judgment which took into account Ontario's motions for leave to intervene and the stipulation between Ontario and EPA, the Court dismissed all of the petitions on the ground that they sought review of action which is not sufficiently advanced for judicial decision at this time. We therefore achieved our objective in this litigation, which was to preserve the legal status of the Costle ruling and to ensure that this status was not impaired by these proceedings.

Basic Issues

Ontario has also participated in proceedings and hearings under Section 126 of the U.S. Clean Air Act dealing with interstate pollution. Ontario intervened in support of petitions filed by New York and Pennsylvania. As the narrow scope of these hearings did not promote full consideration of long range transport problems, Ontario petitioned the EPA on May 28th to expand the scope of the hearings to consider international transport of pollutants. At the outset of the hearings which took place in Washington on June 19th, Ontario's petition was refused by EPA. Nevertheless, on that day, over a period of several hours, Ontario presented scientific evidence through a series of witnesses. At this hearing, Ontario urged EPA to reconsider such basic issues as:

(a) multiple vs. single point sources;
(b) longer range, as well as short range transport;
(c) the connection between primary and secondary pollutants; and
(d) transboundary pollution.

This hearing was a new departure for the EPA in that for the first time it addressed the question of aggregate impact from a number of pollution sources. These Section 126 proceedings are still before EPA and it is unlikely that a decision will be reached before next year.

Finally, on October 7th in Indiana, Ontario petitioned the Air Pollution Control Board of the State of Indiana to oppose an increase in SO_2 emissions requested by the Clifty Creek generating station.

In summary, therefore, we have been involved in legal interventions of an unprecedented kind. These actions have allowed us to work together with other affected jurisdictions such as New York and Pennsylvania and through these activities we have generated important support among the U.S. media and the public.

Unfortunately, the EPA considered the State Implementation Plan relaxations without waiting for the outcome of the interstate proceedings involving, in part, the same sources. In its decision on two plants at Cleveland made in late July, EPA refused to accept the arguments of Ontario, New York and Pennsylvania that long range transport and modelling should be taken into account in reaching its decision. EPA further took the position that in the context of an amendment to a State Implementation Plan, Section 115 of the Clean Air Act, does not require EPA to consider transboundary air pollution in approving an SO_2 relaxation.

EPA also takes the position that the United States has honoured the intent of the Memorandum by controlling its SO_2 emissions "to the extent allowed by the provisions of domestic law". By the same token, the relaxation at issue at the state level in the Indiana case was granted to the company concerned.

We will continue to take our case to the American people and to American courts and administrative tribunals if necessary. Ontario is totally committed to winning the fight against acid rain.

U.S. Forums/On-Site Briefings

In addition to these legal interventions, senior officials of my ministry and myself have appeared before the environmental committee of the U.S. Senate, at hearings held in Albany, N.Y. We have also appeared before U.S. state task forces on acid rain and at numerous university and environmental forums in the United States during the past year to persuade our American neighbours to look at the broad aspects of the acid rain problem before any decisions are made by the U.S. Administration to relax emission levels.

In addition to these direct presentations in U.S. forums, my ministry, in co-operation with our federal Department of External Affairs and Environment Canada, sponsored five on-site briefings on the problem of acidic precipitation for influential American groups during the past summer and fall. Two briefings involved Congressional aides from Washington; one was held for representatives of the print media from major U.S. daily newspapers and wire services; one for legislative and senatorial representatives from the states of Illinois, Wisconsin, Minnesota, Ohio, New York and Connecticut, and one for the California Select Committee on Acid Rain.

Included in the briefings were presentations on Canadian and Ontario programs and policy, scientific evidence on long-range transport from source to receptor, an overflight of the Sudbury area and the endangered region, an information exchange with the local residents in the Muskoka-Haliburton area, and technical presentations on water effects, toxicity studies and terrestrial effects. . . .

We are convinced that all of these communication activities have done much to awaken the American public, including the news media and U.S. legislators, to the acute problem of acid rain and its cumulative damage to our natural environment and resources.

"The Bubble Concept"

In all of our interventions and appearances at hearings, and in our discussions with our U.S. guests on the tours we conducted, we have made it clear that the environmental problem of acid rain is not a Canada versus the United States issue. Rather, we have stressed that it is a North American problem, in fact a global phenomenon, which we on this continent can only solve by action to control the sources of emission in both countries.

By this we do not mean that each separate source be dealt with in an across-the-board, uniform way. Our

approach is what is called "The Bubble Concept" by which regions or systems are identified and required to make an overall reduction in emissions in order to bring the total emission level for that region to an established, acceptable level. The methods of achieving reductions, region by region, would be left to the appropriate authorities in concert with the operators responsible for the emissions.

Another important point to consider is our support of the use of local resources to provide local, social and economic benefit. We strongly believe, however, that this application of resources should not be allowed to inflict environmental damage on other jurisdictions.

This philosophy implies that the long range transport of pollutants, and not just the local impact of emissions, must be considered and that appropriate control and abatement measures be implemented in order to protect both local and distant areas.

A simple example of our position is our attitude toward the swing in the United States to the increased use of high sulphur coal. We are not saying, "Don't burn high sulphur coal." We are saying that this type of coal can be burned cleanly if various technologies are applied in order to reduce emissions of SO_2 and nitric oxides.

Ontario's Abatement Program

Much has been said and written recently about Ontario's abatement program, giving the impression that Ontario has just reached a threshold of abatement activity. This is not the case. Ontario can point to substantial reductions in our SO_2 emissions:

- During the ten-year period, 1970 to 1980, total emissions of sulphur dioxide in Ontario were reduced by approximately 50 per cent, or from 1970 levels of approximately 3.8 million tons to 1.86 million tons last year.
- The Falconbridge smelter in Sudbury now removes 82 per cent of the sulphur in its ores;
- The new control order and regulation on Inco's smelter and iron ore recovery plant in Sudbury requires the company not to exceed an operating level of 803,000 tons per year by 1983. This represents approximately a 70 per cent reduction from historical levels of emissions.
- Another part of environment Ontario's abatement program for the Inco and Falconbridge smelting operations in Sudbury has entailed the establishment of an Ontario-Canada Task Force to investigate all air pollution abatement technology options with the objective of reducing emissions to lowest possible levels. This task force report is expected to be ready sometime next spring.
- Ontario Hydro's coal-fired generating stations, which account for the second largest source of SO_2 in the province, are required by regulation to reduce these emissions by 43 per cent by 1990, regardless of electrical demand. (Parenthetically, I might note that Hydro's emissions would nearly double today if the current energy produced by nuclear production were to be produced by coal-fired plants).
- The regulations on Inco and Hydro deal with 70 per cent of Ontario's 1980 emissions of SO_2.
- Finally, Ontario's newest smelter, operated by Texas Gulf in Timmins (now Kidd Creek Mines Ltd.) has a sulphuric acid plant which removes over 97 per cent of the SO_2 from the zinc smelter, thus reducing SO_2 emissions to about nine tons per day rather than the 368 tons per day which would otherwise have been emitted. This year, the company has built a new copper smelter with a double contact acid plant designed to reduce SO_2 by more than 99 per cent. These emissions will be about four tons per day, as against 400 tons without the acid plant. This is one outstanding example of a company which has met Ontario's standards for pollution controls in new manufacturing facilities.

These measures represent major actions by Ontario which will cause a drastic reduction in our contribution to the acid rain problem. It has been made abundantly clear from the beginning that these are first steps which have been taken well in advance of those taken to date by any other jurisdiction. We are currently assessing our other significant sources that contribute to acid rain with a view to developing control programs to further reduce emissions.

We will do our part to meet whatever requirements are established by the international agreement which is currently under negotiation.

We anticipate major efforts by our federal government to generate a similar initiative from our U.S. neighbours. Without similar response we cannot win the fight against acid rain because total abatement in Ontario would not save Ontario's ecosystem. . . .

Together, Canada and the U.S. have made a good start in cleaning up the Great Lakes if I may use a parallel challenge and response. Ontario's contribution has been, and continues to be, significant.

What's needed now is a similar accord with respect to air quality. The federal government can count not only on Ontario's fullest support, but also on our stubborn insistence that we need an effective international agreement, as soon as possible.

Ministry Estimates 1982/83 — A.P.I.O.S. Activities*

Since 1979, when the Acidic Precipitation in Ontario Study (A.P.I.O.S.) was established to investigate the phenomenon we call acid rain and the long-range transport of air pollutants, a complex research program has been developed to determine sources, deposition, effects, and feasible abatement actions. From a budget of almost $7.0 million in fiscal year 1981/82, we estimate that $9.0 million will be spent in 1982/83 to meet growing research and program requirements.

While the majority of this budget is devoted to research and investigative activities, a portion will be spent supporting Ontario's efforts to persuade U.S. administrators and environmental officials to consider the transboundary and long-term factors involved in airborne pollution and the threat of acid rain to the environment shared by the two countries.

The overall mandate of the Acidic Precipitation Study is to protect Ontario's environment from the detrimental effects of acid precipitation and of other air pollutants which are subject to long range transport.

*Statement by Honourable Keith C. Norton to The Standing Committee on Resources Development, May 1982.

At this time, I would like to bring you up-to-date on our program and major research activities for 1982/83.

1) **Atmospheric Processes Studies**

During 1981/82 Ministry of the Environment scientists developed and validated a statistical model for estimating the total deposition of sulphur throughout the province. In fiscal year 1982/83, this model will be expanded to include oxides of nitrogen (NO_X).

Staff at the Ministry anticipate that both an accurate assessment of current SO_2 and NO_X emissions in the province and an updated inventory of SO_2 emitters of 100 tons per day and greater will be available this year for eastern North America. A preliminary inventory of NO_X emitters in eastern North America will be completed as well.

Few people today doubt the effects of acid precipitation on our aquatic ecosystems. However, there are still many "doubting Thomases" on the subject of the long-range transport and deposition of air pollutants. For this reason, considerable effort will be expended over the next year in developing and validating more sophisticated Long Range Transport models.

The monthly and event deposition monitoring networks which we expanded in 1981/82, will continue routine sampling of wet and dry deposition, airborne particulate matter and gaseous sulphur and nitrogen.

The cumulative or monthly network will assist in determining acid loadings in various areas in Ontario; whereas the event or daily networks will assist in linking specific emission sources to receptor areas. At a limited number of sites, we will begin monitoring other airborne pollutants such as dissolved SO_2, mercury and organics.

Much has been written and much is known about sulphur dioxide and its effects on the environment. As part of our ongoing research on the effects of airborne pollutants and the long-range transport of these pollutants, the Air Resources branch of the Ministry will consider the levels and impact of oxidants in Ontario. We are considering the sources, transport, ground-level concentrations, relationship to nitrogen oxide and hydrocarbon emissions, control strategies, costs of control and environmental damage estimates associated with oxidants. It is anticipated that a preliminary report will be available later this year.

2) **Aquatic Effects Studies**

I have already made reference to the skepticism surrounding long range transport of air pollutants. I believe sincerely that I would be hardpressed to find more than a handful of skeptics concerning the impact of acid rain on our aquatic ecosystems.

Thousands of lakes and streams are in jeopardy today from the effects of acid rain. The fish populations and the viable tourist and recreational economics which depend on them are being severely stressed.

In 1982/83, work will continue at our calibrated watersheds in the Muskoka–Haliburton area. Detailed limnological studies will continue on 8 lakes and 32 watersheds in order to develop and refine models that predict the impacts of atmospheric deposition on various chemical parameters.

In addition, intensive, integrated watershed studies will be conducted in northeastern and northwestern Ontario. . .

This year, as in past years, intensive studies will be carried out during spring and fall run-off to determine the impact of these "shock" loadings on selected lakes and streams.

Fishery resources are dwindling in affected lakes due to subtle shifts in age class distributions. Since the effects of acid rain on fisheries are known to be subtle, emphasis is being placed on sublethal physiological responses. One such set of experiments will involve the determination of the sublethal response of fish species during pH/aluminum stress on respiration and metabolism.

Field experiments will be conducted during 1982/83 to evaluate the effects of spring run-off and acidic pulses on embryo-larval development and growth of indigenous fish species. As well, work will continue on toxicity thresholds (including metals uptake) for various indigenous fish species.

In May, 1981, the Ministry released its first survey on the acid sensitivity of lakes in Ontario. Since that time, further sampling of additional lakes has taken place and the Ministry has released updated information of our lake sampling activities. Lake sampling will continue during 1982/83.

The Ministry of the Environment is working closely with many branches of government in many jurisdictions. In Ontario, we are working now on an integrated, intensive water quality and fish population study with the Ministry of Natural Resources. A select number of lakes in the Algonquin Park area will be used in this study.

3) **Terrestrial Effects**

Concern is mounting over the potential for damage to our terrestrial ecosystems caused by acid precipitation. In response to this concern, Ministry scientists are attempting to determine the present status and sensitivity of soils and vegetation to acid deposition.

Experimental studies with simulated acid rain on various species of vegetation are continuing. Baseline surveys of vegetation and soils will be conducted to establish the status for chemical constituents so that future changes caused by atmospheric deposition can be detected.

In addition to liming experiments being carried out in affected lakes, in northeastern Ontario we will be conducting experiments on tree seedling plots in an attempt to determine whether the addition of lime to forests can effectively be used in forest plantings to offset acidic precipitation.

4) **Socio-Economic Investigations**

Ontario's citizens are aware of the acid rain issue and the need for a resolution to this serious threat to our environment. Our extensive research program into this problem includes a socio-economic component. In fiscal year 1980/81, three major economic studies were initiated and are now receiving extensive peer review. The work in this area is pioneering, hence there is a necessary focus on methodological development.

These studies include an assessment of the implications of acid rain on tourism and recreation, a survey of the values and perceptions people hold for environ-

mental resources threatened by acid rain and examinations of the effects on other sectors including forests, agriculture, buildings and commercial fisheries. The methods developed in these studies can be used to update estimates of effects as well as to develop and evaluate policies.

My Ministry is planning to release an overview or synthesis report in September of this year to present the technical information collected in our studies as well as explain the methodologies.

It remains difficult to demonstrate a relationship between acid rain and human health, and to date no North American effects have been described scientifically. There is, however, increasing concern here and abroad that the acidification of water supplies could result in increased concentrations of various metals from rock, soil or plumbing and that this might result in adverse health effects.

My Ministry is planning an overview study of possible health effects related to acid deposition which we propose to launch this year.

Ontario has taken major steps to reduce its contribution to the acid rain problem.

Inco, generally acknowledged to be the largest single point source of sulphur emissions in North America, had cut emissions by about one half during the 70's. In May 1980, knowing that tougher controls were needed, the Ontario Government ordered Inco to cut back a further 25 per cent by the end of 1982.

The Falconbridge smelter in Sudbury now removes 82 per cent of the sulphur in its ores.

Ontario Hydro, whose coal-fired plants together form the second largest source of SO_2 in the province, is now under government regulation to reduce emissions by approximately 43 per cent from current average levels by 1990. Hydro is required to meet the established emission limits regardless of any increase in domestic power demand or in export of power.

Finally, Ontario's newest smelter, at the Kidd Creek Mine in Timmins, has a sulphuric acid plant which removes over 97 per cent of the SO_2 from the zinc smelter, thus reducing SO_2 emissions to about nine tons per day rather than the 368 tons per day which would otherwise have been emitted. This year, Kidd Creek has built a new copper smelter with a double contact acid plant designed to reduce SO_2 by more than 99 per cent. These emissions will be about four ton per day, as against 400 tons without the acid plant.

Our goal is to reach the level of emissions our environment can tolerate without suffering.

The Government of Ontario formed the Ontario/Canada Task Force to investigate emissions in the Greater Sudbury Area. This Task Force, will identify and enumerate the environmental, economic and social consequences of alternative air pollution abatement programs for both Inco and Falconbridge; develop abatement cost functions; determine the economic impact of abatement on the two companies and the community; evaluate the consequences of alternative enforcement policies; and compare abatement costs with expected benefits of abatement programs.

In addition, my staff is exploring possible abatement action on other sources.

The foregoing is a brief synopsis of Ontario's activity on a scientific level in trying to come to grips with acid rain. Our research is telling us clearly that something must be done and we have mounted a major effort to see that action is taken both in Ontario and elsewhere.

5) **Federal/Provincial Co-ordination**

The Ontario Government has the day-to-day authority for setting and enforcing pollution standards. Our problem would, therefore, be minimal if acid rain were a local rather than an international problem. Because of the international scope of the problem, Ontario has been working very closely with the federal government and other provincial governments to examine the problem and to propose various abatement strategies. At our most recent negotiations in Washington, D.C. (February 24, 1982) Canada put forward a proposal which calls for a 50% reduction in current acid gas emissions in both the United States and Canada. Ontario is on record as endorsing this position. We are prepared, if the United States agrees to this percentage reduction, to sit down with our federal government and the provinces concerned to negotiate further reductions from Ontario sources as part of Canada's overall commitment.

Without a commitment from the United States similar to the one Canada is prepared to make, we cannot win the fight against acid rain. We anticipate a resumption of negotiations in June of this year. In the interim, the working groups established under the Memorandum of Intent and in which Ontario is an active participant, will continue to provide information which will assist in the preparation of a bilateral agreement to address the problem of the long-range transport of air pollutants.

6) **Legal Initiatives/Interventions**

Ontario is totally committed to winning the fight against acid rain. Staff of the Ministry's Legal Services Branch will continue, during 1982/83, to assess the effectiveness of available legal instruments in regulating acid gas emitters. In addition, on-going reviews of current Regulations and Control Orders for sources of SO_2 and NO_X will take place in conjunction with current research on best available abatement technologies.

In 1981, 4 interventions were filed in the United States. On January 4, 1982, the Province of Ontario submitted a consolidation of testimony presented by Ontario at the hearing in Washington, D.C. on June 19, 1981 to the U.S. Environmental Protection Agency. In addition, this submission incorporated information which brought up-to-date all evidence which Ontario had offered in respect of the proceedings before the EPA.

Ontario is extremely concerned about the continued relaxation of State Implementation Plans under Section 110 of the Environmental Protection Act, and consideration will be given to intervening, as appropriate.

As well, we will be monitoring legal developments in the United States as they affect Ontario and Ontario's position on the long-range transport of air pollutants.

ERRATUM: Page 7 — "Major SO_2 and NO_X Emitting Areas" — geographical area #10 should read "East Missouri", *not* "East Montana".

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IMPACT OF ACID RAIN

The phenomenon of acidic precipitation, commonly known as acid rain, is acknowledged by scientists and governments to be one of the most pressing environmental issues facing widespread areas of North America, Europe and Scandinavia.

Research attributes most of the acid rain in North America, and elsewhere, to pollution resulting from emissions of oxides of sulphur and nitrogen. This acid pollution is formed by a complex series of chemical and physical processes. The chemistry is only partially understood at present, but essentially the problem begins when sulphur and nitrogen compounds are emitted into the atmosphere as a result of man's industrial activities and his use of modern transportation vehicles.

The sulphur and nitrogen emissions originate chiefly from the combustion of fossil fuels, such as coal and oil, from power generating plants, ore smelting, petroleum refining, industrial furnaces and from vehicles of all kinds.

Acid rain evolves through a cycle of four consecutive stages — sulphur and nitrogen emissions, long-range atmospheric transport, transformation of chemical properties, and, finally, fallout of these pollutants to earth through either precipitation or dry deposition.

Sulphur and nitrogen compounds, emitted primarily in the form of sulphur dioxide (SO_2) and oxides of nitrogen (NO_x), are transported by winds and air currents at high and low altitudes. Meteorological conditions can carry these pollutants hundreds to thousands of miles from their point of emission, allowing time for chemical transformation to acids. They return to earth eventually in the form of "wet deposition" (acidified rain or snow) — or as "dry deposition" (particulate matter or gases) — on soil, forests, vegetation and water.

This fallout of destructive acid rain, acidic snow, or in lesser degree dry particulate matter, results from long-range transport of air pollutants affecting many regions of the world. Frequently, the areas which produce pollution are unaffected by it, either because its fallout is far away, or the local lakes and soils are well buffered with alkaline bedrock or chemistry.

Scientists know acidic precipitation is having severe ecological effects on the natural environment, particularly lakes, rivers and fisheries, man-made structures and buildings, and fear long-range effects on forests and other vegetation.

Worldwide Impact and Concern

The chief and immediate concern about acid rain is that it ultimately affects aquatic life in lakes and watersheds which have quartzite or granite based geology, rather than limestone bedrock. These lakes and rivers are sensitive to acidity because they have very little "buffering"* or neutralizing capabilities.

This condition is evident in many of the lakes in Canada's Precambrian Shield, including the Muskoka and Haliburton lakes and many others in northern resort regions, where little natural limestone exists.

Since the mid-50s, hundreds of such lakes in eastern North America (FIG. 1), Scandinavia and parts of western Europe which have little buffering ability have become so acidic they can no longer support fish and aquatic life. Ontario Government scientists have documented that there are some 120 lakes in the Province, mostly centred around Sudbury, which are fishless because highly acidic conditions have inhibited reproduction. Well over 200 lakes in the Adirondack mountains of New York State, and hundreds in southern Norway and Sweden have been found to be suffering from a similar plight.

FIG. 1
North American Areas Containing Lakes Sensitive to Acid Precipitation

Source: James N. Galloway and Ellis B. Cowling, Journal of the Air Pollution Control Association 28, no. 3 (March 1978)

In addition, it has been found that many **well buffered** lakes can lose an entire year's hatch of valuable sports fish due to the acidic shock effect of spring run-off, when the pollutant-laden winter accumulation of snow suddenly melts into waterways. Heavy rain episodes can also cause the same acidic shock effect.

While many of the aquatic effects of acid rain have been documented, data related to other possible impacts are just beginning to be compiled. There is considerable evidence to support the premise that if the current trend to increased acidity continues, the growth of forests and crops may be adversely affected

*"Buffering" is the ability to neutralize or stabilize free hydrogen ion input, or acidity, and is usually present in regions where limestone or alkaline soil chemistry is prevalent.

Concern and Effects in Ontario

While the acidic condition of Scandinavian lakes and those of the Adirondack mountains have been known for several decades, the scope of the vulnerability of Canadian lakes far removed from industrial activity were recognized much more recently.

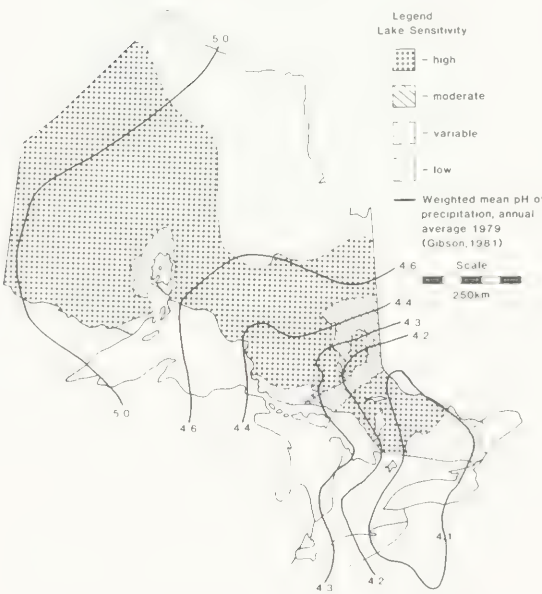
Scientists estimate that, if 1980 levels of acid loadings remain constant or increase over the next 10 to 20 years, Ontario could lose much or all of the aquatic life in tens of thousands of susceptible lakes unless effective abatement measures are taken (FIG. 2). A major program is well underway in Ontario to identify the current state of susceptible lakes (see "Aquatic Studies in Ontario", page 17).

Thousands of lakes in Quebec, and the Atlantic Provinces are also susceptible, and many are already afflicted or threatened since they lie in the path of acid emissions from the interior of the continent.

The severity of the situation in Ontario, and the need for quick abatement action, results from the increase in acidity of precipitation over the past several decades. Acid rain has increased to the point where the

FIG. 2

Lake Acid Sensitivity in Ontario as Predicted by Bedrock Composition



This map is intended only as a general regional guide to sensitivity of lakes to acid precipitation. Surficial geology, hydrologic setting and man's influences in many cases will control lakes acid sensitivity. Isopleths indicate annual mean pH of acidic precipitation.

average pH of rainfall for that part of Ontario lying south of the 50th parallel (roughly in line with the "continental divide") is less than 5.0. Many regions of the Province regularly receive rain of pH 4.0 to 4.5. (see "the pH Parameter", page 3)

The nature of aquatic and terrestrial effects of acidic precipitation, as well as studies and abatement measures being undertaken by the Ontario government are described in detail on page 17. Implications on human health are described on page 22.

Transboundary Pollution

Long-range air transport of pollutants and acidic precipitation are closely related. Prolonged transport of sulphur and nitrogen compounds allows time for the chemical and physical conversion from sulpnur dioxide and nitrogen oxides into acidic compounds.

Prevailing weather conditions in eastern North America foster the large-scale movement of pollutants within both Canada and the United States as well as across their border, so that the movement of pollutants are regional issues.

Ontario has played a major role in bringing the phenomenon of acid rain, and its transboundary effects, into public focus.

Ontario Environment Minister Harry Parrott stated in 1978 that: "This movement of pollution across national boundaries means that an effective long-term solution can only be developed if all jurisdictions work together. There is little doubt that the acid rain impact in Ontario would not be reduced significantly even if all Ontario's emission sources are eliminated. This underlines the great importance to Ontario of a United States and Canada accord".

Because of transboundary pollution, the acid rain situation creates numerous national and international regulatory problems in that the air pollution standards can differ from jurisdiction to jurisdiction. Therefore lax standards can allow pollutants to have a direct impact on the natural resources of another jurisdiction. Canada and the United States are consequently exploring ways to integrate and co-ordinate their scientific and regulatory programs, and to reach a formal accord for abatement action.

A first major step toward negotiation of a treaty between the two countries was taken in Washington on August 5, 1980 when Canadian Environment Minister John Roberts and U.S. Secretary of State Edmund Muskie signed a memorandum of intent to curb acid rain and resolve international air pollution problems. The agreement establishes five work groups to lay the foundation for an air quality treaty to be negotiated by 1982, which will demand vigorous enforcement of anti-pollution standards.

Fundamental Chemistry

Not all the acid in rain comes from pollution; "clean" or "normal" rain is slightly acidic due to adsorption of small amounts of natural atmospheric carbon dioxide which, when dissolved in water, forms a weak acid, carbonic acid, similar to that found in soda water or carbonated soft drinks. Rain is also affected by natural sources of air pollution such as forest fires and volcanos.

However, "acid rain" in northeastern North America is frequently many times more acidic than normal rain because of sulphur and nitrogen emissions from man's activities.

Sulphates are believed to cause about two-thirds of the acidity in precipitation and nitrates responsible for about one-third, throughout most of Ontario.

The rate of the conversion reaction of oxides into acids, and exactly how acids are formed in the atmosphere during long-range transport, is still an area of intensive research. There are several complicated pathways or mechanisms by which oxidation can occur. Which path is taken is dependent upon numerous factors such as the concentration of heavy metals in airborne particulate matter, the intensity of sunlight, humidity and the amount of ammonia present. For example, airborne particulate metals such as manganese and iron catalize or speed-up the conversion of sulphur dioxide to its oxidation products, sulphuric acid and sulphates.

The process by which acids are deposited through rain or snow is called "wet deposition". Another atmospheric process, known as "dry deposition", is the process by which particles such as fly ash, or gases such as sulphur dioxide or nitric oxide are deposited, or adsorbed onto surfaces. While these particles or gases are not always in an acidic state prior to deposition, it is known that they can be converted into acids after contacting water in the form of rain, dew, or fog following deposition. The precise mechanisms by which dry deposition takes place, and its effect on soils, forests, crops and buildings, are not adequately understood. Much research is being undertaken to clarify the overall acid deposition problem.

Acid Rain — the pH Parameter

Scientists gauge the acidity or alkalinity of a solution by a parameter called the pH, which is a logarithmic measure of the hydrogen ion concentration on a scale ranging from 0 to 14 (FIG. 3). On the pH scale, a chemically neutral solution has a value of 7, which is midway on the scale. The greater the acidity, the lower the pH value. A change of one pH unit downward implies a tenfold change in the hydrogen ion concentration, or a tenfold increase in acidity; a change of two is a hundredfold. If for example, a pH is 4, it is 10 times more acidic than a pH of 5; a pH of 3 is a hundredfold more acidic than a pH of 5.

Due to the carbon dioxide naturally present in the atmosphere, the pH of normal or "clean rain" in eastern North America is about 5.6.

In areas of southern Ontario, such as the Muskoka and the Kawartha Lakes, the pH of the rain is often found to be 4.5 to 4.0 range, meaning that the rain is many times as acidic as that of "clean rain". Aquatic life in susceptible lakes is considered to be vulnerable when the pH level of the lake lies in the range of 5.5 to 5.0.

There is widespread concern that if these acidic concentrations are sustained over long periods, serious detrimental effects will be experienced by aquatic and terrestrial ecosystems and these acidic effects will remain for years, or possibly become irreversible.

FIG. 3
The pH Acidic Parameter

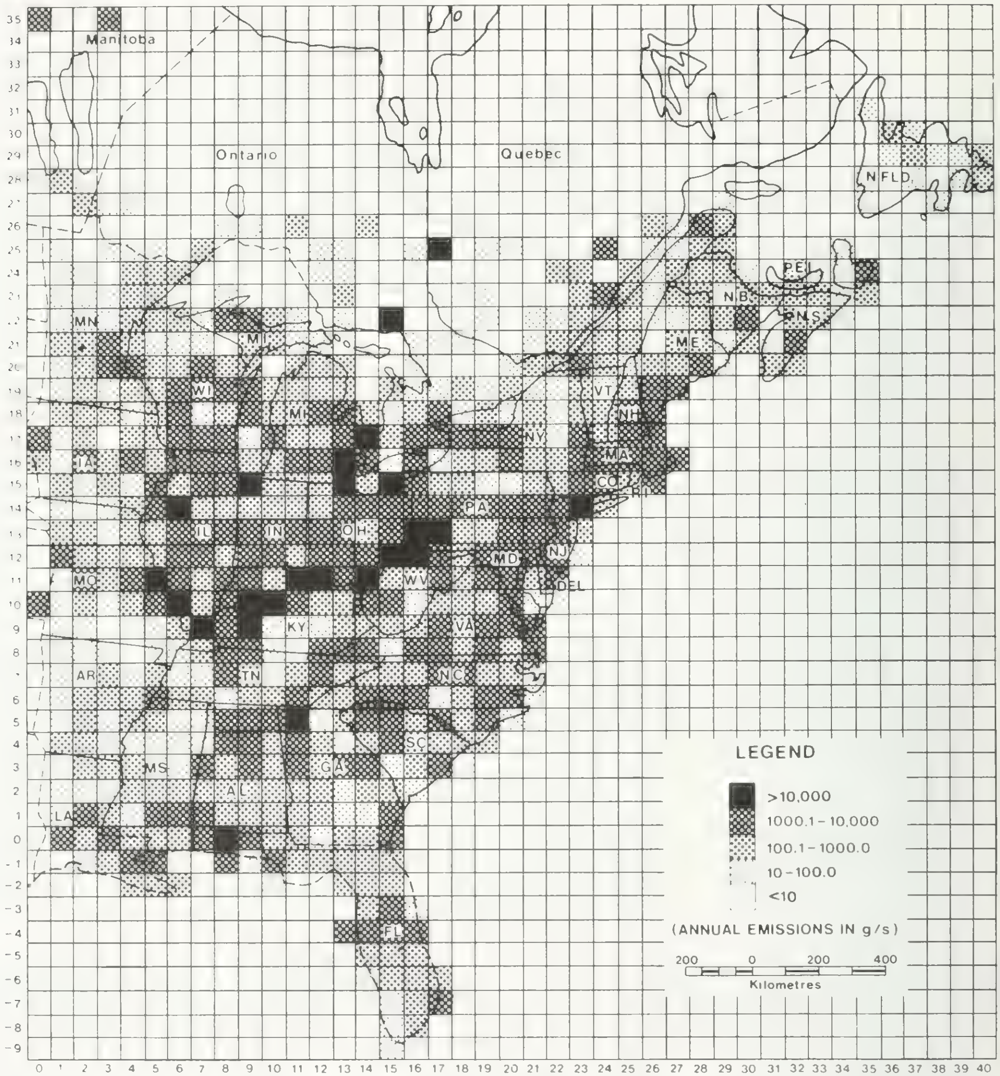
14.0	
12.4	Lime (calcium hydroxide)
11.0	Ammonia (NH_3)
10.5	Milk of Magnesia
8.0-8.5	The Great Lakes (annual mean)
8.3	Sea Water
8.2	Baking Soda
7.4	Human Blood
7.0	Neutral — Distilled Water
6.6	Milk
5.6	"Clean" or Normal Rain
5.0	Carrots
4.2	Tomatoes
4.0-4.2	Annual mean pH of rain in Muskoka/Haliburton area
3.0	Apples
2.2	Vinegar
2.0	Lemon Juice
0.0	

ALKALINE (14.0 – 7.0); ACIDIC (7.0 – 0.0); ACID RAIN (5.6 – 0.0)

Giant smoke stacks are major precursors of acid rain, causing transboundary pollution

FIG. 4

Magnitude and Distribution of Sulphur Dioxide (SO_2) Emissions



Eastern North America — Major SO_2 Emitting Areas

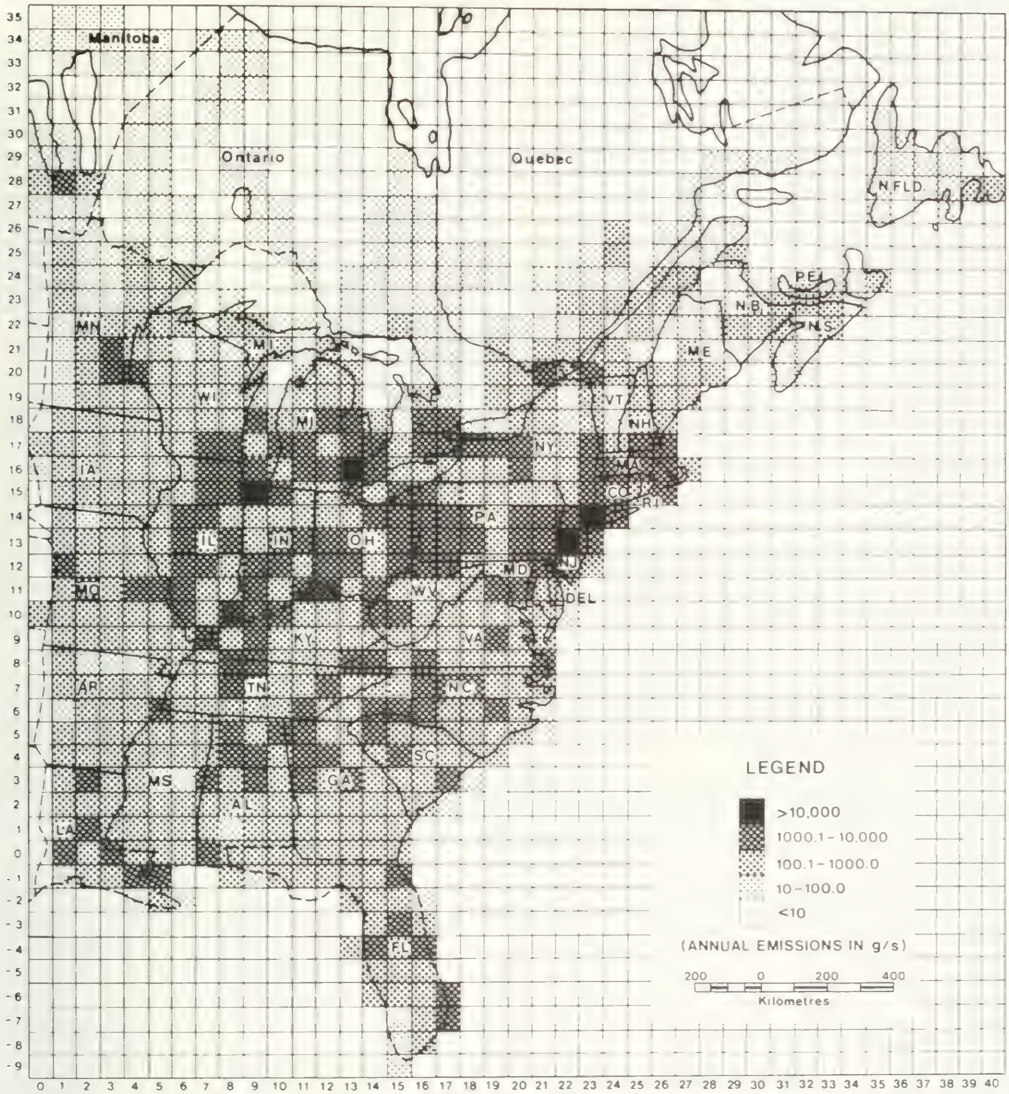
	Geographical Area	Grams/Second
1.	East and West Pittsburg, Ohio River Valley, W. Virginia	75,586 0
2	Sudbury, Ontario	43,617 8
3	W. Kentucky, Louisville, S. Indiana	41,462 5
4	Toledo, Ohio, Detroit, Michigan	40,117 7
	Lower and Central Ohio River Valley, W. Virginia (Clarksburg)	33,863 8
6	East and West Cincinnati, Northern Kentucky	33,514 4
7	New York, New Jersey	29,868 1
8	West Illinois, East Missouri	29 514 9
9	Indianapolis, Indiana	23,507 3
10	Mobile, S. Alabama	23,352 5
11	Chicago, Illinois	22,173 7
12.	Western Kentucky	21,281 2
13	Rouyn-Noranda, Quebec	16,336 0

Geographical Area is defined as 160 km. x 160 km. grid square

Source. U.S. emission rates from the SURE II data base are 1977-78 emission rates for point sources, and 1973-77 emission rates for area sources. Canadian data from Environment Canada are estimated 1978 emission rates for major SO_2 point sources, and 1974 emission rates [illegible]

FIG. 5

Magnitude and Distribution of Emissions of Nitrogen Oxides (NO_x)



Eastern North America — Major NO_x Emitting Areas

	Geographical Area	Grams/Second
1.	New York: New Jersev	52.024.1
2.	Chicago, Illinois	30,867.0
3.	Toledo, Ohio; Detroit, Michigan	25,303.9
4.	East and West Pittsburgh; Upper and Central Ohio River Valley	23,132.7
5.	Cincinnati, Ohio; Northern Kentucky	16,536 6
6.	Cleveland, Ohio, West Pennsylvania	15,54[illegible]
7.	West Kentucky; South Indiana	12,16[illegible]
8.	East Missouri; West Illinois	11,78[illegible]
9	[illegible]	[illegible]
10	[illegible]	[illegible]

Geographical Area is defined as 160 km. x 160 km. grid square

Source: U.S. emission rates from the SURE II data base are 1977-78 emission rates for point sources, and 1973-77 emission rates for area sources. Canadian data from Environment Canada are estimated 1978 emission rates for major SO_2 point sources, and 1974 emission rate for other point and area sources

DEFINING THE PROBLEM

Canada-U.S. Research Group

The Canada-United States Research Consultation Group on the Long-Range Transport of Air Pollutants (LRTAP) was established in 1978 by the two governments to co-ordinate research studies and programs, and to expedite the exchange of scientific information.

A preliminary report, by the Group, issued in October 1979, points out that adverse effects from pollutants transported over long distances result from the accumulation of material deposited over a long period at low concentrations, and the synergistic or additive effects of a combination of materials. This is in contrast to local pollution situations where damage, or effects on health and comfort, result usually from elevated ambient air concentrations during an "air pollution episode" over a limited time period. Conventional air quality standards therefore are not designed for these more subtle and cumulative long-term effects.

Origin and Amounts of Emissions*

The Group's recent report gives 1975 estimates of sulphur dioxide and nitrogen oxide emission for the two countries, along with maps showing the geographical distribution of emissions. (FIGS. 4 and 5)

The report is concerned basically with eastern North America, which embraces the industrial heartlands of both countries, wherein lie most of the aquatic ecosystems which are vulnerable to acidic precipitation. For example, three-quarters of the total Canadian emissions of SO_2 and two-thirds of total Canadian emissions of NOx are east of the Manitoba/Saskatchewan border.

*all tonnage throughout report in "standard" or short tons.

Annual sulphur dioxide (SO_2) emissions were estimated at 5.5 million tons in Canada and 28.5 million tons in the United States. It was projected that there would be modest SO_2 increases by the end of the century, despite abatement measures. However, this projection could change in light of the U.S. government's decision to convert major utilities from oil and gas to coal without adequate abatement equipment.

Annual nitrogen oxide (NOx) emissions were estimated at 2.1 million tons in Canada and 24.4 million tons in the United States. Substantial increases in these emissions are expected if consumption of fossil fuels continues to increase, particularly in the United States with its larger population.

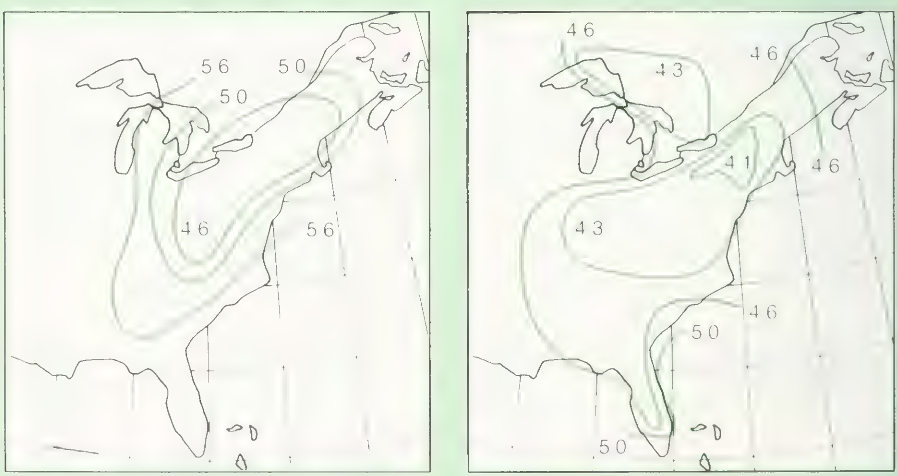
Trends in these emission rates indicate that nitrogen oxides will contribute increasingly to the acidity of precipitation. Available pollution abatement methods and technology could reduce total SO_2 emissions. New technology to reduce NOx emissions from stationary sources is currently being developed.*

The report concludes that approximately $^2/_3$ of the sulphur emitted into the atmosphere of eastern North America is deposited there, with the remainder leaving the atmosphere of the region, primarily to the east. In eastern Canada about $^2/_3$ of that deposited falls in precipitation, and the remainder during dry periods.

No attempt was made to attribute deposition or effects, at specific sites to specific sources, since conclusions were largely obtained from atmospheric modelling. The actual measurement of depositon is of great importance and will be addressed in future reports. Studies are underway to develop a better scientific understanding of the atmospheric behaviour of both nitrogen and sulphur compounds.

*see Research Summary "Controlling Nitrogen Oxides", U.S. EPA Office of Research and Development (EPA-600/8-80-004), published February 1980.

FIG. 6 Regions affected by acid rain



1955-56 **1975-76**

Isopleths showing Annual Average pH for Precipitation in Eastern North America (modified from Likens et al. 1979).

Meteorological Factors

Prevailing wind and weather patterns are the overriding factors in determining the extent of transboundary pollution between the United States and Canada. For this reason both countries are refining predictive meteorological modelling techniques to better link and assess the source and receptor aspects of the problem.

The Canada-U.S. Research Group's report states that the net flux of sulphur is from south to north across the Canadian border. On an annual average basis, about three to four times as much sulphur moves across the boundary from the United States to eastern Canada as in the opposite direction. The report states that sulphur flux from U. S. sources to eastern Canada air space is comparable to *total* Canadian emissions in volume—about 5.5 million tons. (FIGS. 7 and 8)

The estimates in the report are based largely on atmospheric modelling, a science being upgraded constantly in design and accuracy. Meanwhile, field monitoring equipment and instruments to measure and analyze the specific local concentration of acid rain have been established throughout the eastern continent to enable pinpointing of pollution sources.

The monitoring, research and computer modelling work being carried out by both countries is especially relevant to abatement programs for stationary sulphur sources of emissions.

With the exception of power generation and industrial combustion, the major sources of nitrogen oxides are related to transportation vehicles and are therefore more difficult to control, except through internal combustion design and regulatory mechanisms.

When an inventory of point or area sources is coupled with meteorological data and with deposition fields and monitored effects, information is obtained which can be applied to abatement strategies. It can be determined what sources have an effect on a specific sensitive area and the share each source contributes to that effect. It can then be determined, which sensitive areas will benefit from abatement at any of these sources.

Eastern North America — Major SO_2 and NO_x Emitting Areas

Geographical Area	Grams/Second
1. East and West Pittsburg; Upper and Central Ohio River Valley	98,718.7
2. New York; New Jersey	81,892.2
3. Toledo, Ohio; Detroit, Michigan	65,421.6
4. Western Kentucky; South Indiana	53,623.7
5. Chicago, Illinois	53,040.7
6. Cincinnati, Ohio, North Kentucky	50,051.0
7. Cleveland, Ohio, West Pennsylvania	47,997.7
8. Sudbury, Ontario	43,915.3
9. Lower and Central Ohio, River Valley; Clarksburg, Virginia	42,401.3
10. East Montana; West Illinois	41,298.8
11. Indianapolis, Indiana	30,202.9
12. Western Kentucky	25,849.3
13. Mobile; South Alabama	24,138.5
14. Toronto, Ontario	18,584.7
15. Rouyn-Noranda, Quebec	16,402.2
16. Southern Louisiana	14,596.8

Important Storm Trajectories over Major SO_2 and NO_x Emitting Areas

FIG. 7 SUMMER

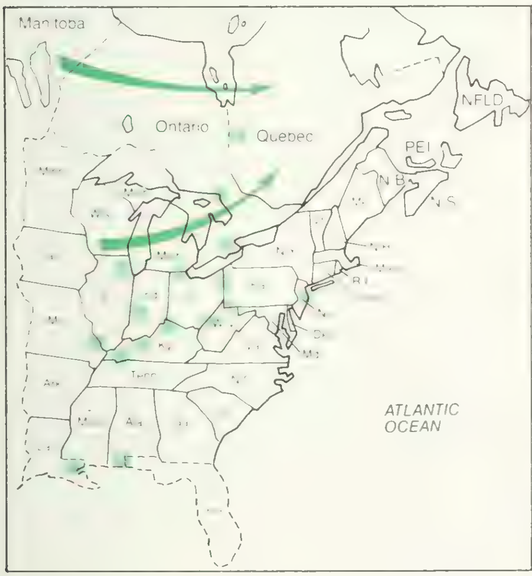
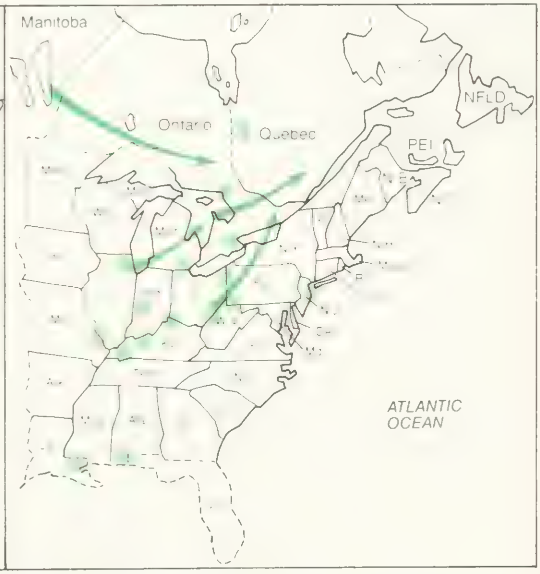


FIG. 8 WINTER



Geographical Area is defined as 160 km. x 160 km. grid square
Source: U.S. emission rates from the SURE II data base are 1977-78 emission rates for point sources, and 1973-77 emission rates for area sources Canadian data are from Environment Canada are estimated 1978 emission rates for major SO_2 point sources, and 1974 emission rates for other point and area sources. Storm trajectories by J. Kurtz, meteorological scientist, Environment Ontario, based on 40 years of data. U S Weather Bureau

Ontario Atmospheric Deposition Studies

Two new and enlarged networks of monitoring stations to measure fallout and to identify sources of acid rain were set up at 45 locations throughout the Province in the spring of 1980. (FIG. 9)

These monitoring stations will play a vital role in Ontario's ongoing research to determine the quantity, acidic concentrations and impact of acid rain and snow, as well as dry particulate matter, falling in both the sensitive areas and other parts of the Province. The program will also identify more clearly the relative contributions of this pollution from numerous continental sources. The monitoring networks, known as Environment Ontario's "Atmospheric Deposition Studies", are one of the numerous scientific investigations taking place under the overall Acid Precipitation in Ontario Study (APIOS).

This deposition monitoring program supplements Ontario's existing Province-wide network of more than 1,400 instruments which comprise the Air pollution Index and Alert System, enabling Environment Ontario to control air pollution by enforcing reduction of emissions of SO_2 and particulate matter (page 14).

The two new monitoring networks are complementary but yield different information. One is designed as a "true event" network sampling precipitation and particulate matter on a daily weather basis. The other is a "cumulative" network sampling precipitation and particulate matter on a monthly basis. Both are designed to collect wet and dry deposition. All samples collected are analyzed at the Ministry's Toronto laboratories using special equipment required to detect low levels of airborne contaminants.

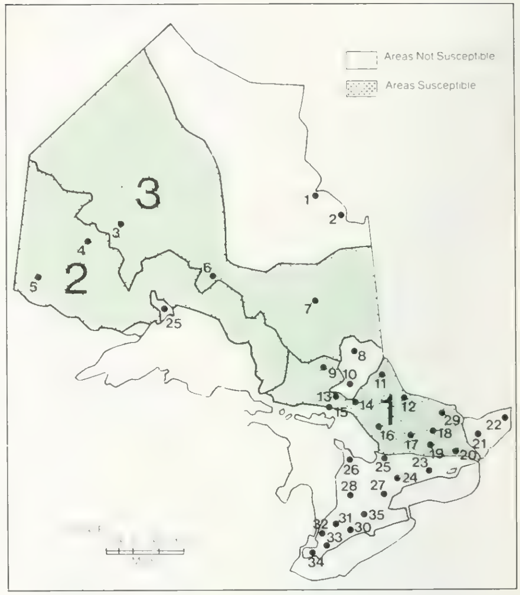
Daily "Event" Network

The "event" network is located in the vicinities of London, Dorset and Kingston, with each centre having five collection or monitoring sites clustered within a radius of 50 to 100 kilometres. The Dorset location was chosen because of the major acid rain studies already in progress there. The London and Kingston areas were chosen to provide information on the contribution to local acidic deposition from major northeastern continental sources.

This network utilizes highly sensitive equipment at each of its 15 monitoring sites for the sampling of atmospheric pollutants. The instrumentation is specifically designed to sample particulates and gaseous sulphur and nitrogen compounds for 24-hour periods.

The daily data generated from monitoring and sampling at these centres, when coupled with relevant meteorological data, such as surface and upper level weather observations, can aid in the identification of the major continental sources contributing to acidic precipitation in Ontario. The necessary meteorological data are obtained by the Ministry directly through a computer link with the Atmospheric Environment Service of Environment Canada.

FIG. 9
Locations of Ontario's Acid Rain Monitoring Sites*



*Cumulative Sites—monitored monthly

1. Attawapiscat
2. Moosonee*
3. Pickle Lake
4. Ear Falls
5. Experimental Lakes Area*
6. Nakina
7. Moonbeam
8. Gowganda
9. Ramsey
10. Hanmer
11. Bear Island
12. Mattawa
13. Lively
14. Burwash
15. Killarney
16. McKellar
17. Dorset
18. Whitney
19. Wilberforce
20. Kaladar
21. Smiths Falls
22. Dalhousie Mills
23. Campbellford
24. Uxbridge
25. Dorion
26. Shallow Lake
27. Milton
28. Palmerston
29. Golden Lake
30. Pt Stanley
31. Alvinston
32. Wilkesport
33. Merlin
34. Colchester
35. Waterloo

Note
*Proposed sites

"Cumulative" Monthly Network

The "cumulative" network consists of 30 sites, ranging in location from the Windsor area northwest to the Kenora region and northeast to James Bay, southward down the Ottawa River, and westward to sites scattered throughout south central Ontario.

Each of these monitoring stations is equipped with automatically operated "double bucket" collectors to measure the accumulated "wet" and "dry" deposition, with samples collected monthly for laboratory analysis. In addition, 20 of these stations are equipped with instrumentation to collect monthly samples of particulate sulphate, nitrate, ammonium and gaseous SO_2 in their immediate vicinity.

Together, the two monitoring networks enable scientists to gather needed information on the range, extent and strength of acidic precipitation in all regions of the Province.

By applying all of these data to information gleaned from Ministry studies focused mainly in the Muskoka/Haliburton and Sudbury regions — areas which are environmentally vulnerable, Environment Ontario expects to be able to extrapolate its current and anticipated scientific findings on lake deterioration rates due to acid rain input to widely scattered regions of the entire Province.

Pinpointing the Sources

The utility and industrial sectors responsible for major emissions of SO_2 and NOx in each country were pinpointed by the Canada-U.S. Group's October 1979 report. These pollution sectors and their estimated emission quantities point up the different mix of pollution sources in each country, and also indicate where abatement action must be taken.

SO_2 Emissions

Utilities, or power generating plants, account for the largest single share of man-made SO_2 emissions in the United States,—roughly two-thirds, amounting to 18.6 million tons annually. This compares to a total of only 0.7 million tons of SO_2 emissions from utilities in Canada. Ontario utilities account for less than 0.5 million of this amount.

The non-ferrous smelting sector accounts for the largest SO_2 emissions in Canada, 2.4 million tons, or over 40 per cent of the Canadian total. Similar smelting operations in the U.S. account for 2.8 million tons. Ontario accounts for about half of the Canadian smelting total, the major source being the nickel mining and smelting complex in the Sudbury area.

NOx Emissions

About half of the nitrogen oxide emissions in North America are due to transportation-related sources — cars, trucks, trains and airplanes. Power generation and other combustion sources contribute the other half.

In the United States, power generating plants account for roughly one-third of all nitrogen oxide emissions, or 6.8 million tons, compared with only 0.2 million tons in Canada per annum, indicative of the higher ration of hydro and nuclear generating capacity in Canada as compared to coal in the U.S. Nearly 20 per cent of total Canadian NOx utility emissions, or 0.06 million tons, are attributed to Ontario power generation.

NOx emissions from non-ferrous smelting are negligible in both countries.

U.S. Power Generation

The U.S.-Canada Research Consultation Group reports that the highest density of sulphur dioxide emissions is in the upper Ohio Valley (eastern Ohio, northern West Virginia and western Pennsylvania) where a number of large power plants burn high sulphur coal with little control of their sulphur emissions. (FIG. 10)

United States sulphur emissions from the utility sector have nearly quadrupled over the past 25 years. (FIG. 11)

With the announced program of a substantial increase in the use of coal as a source of energy in the United States, there is a need to reduce SO_2 and NOx emissions from both existing power plants and the projected 300 new plants to be built in the U.S. during the '80s and '90s.

Legislation passed in 1972 in the United States required new power plants burning coal to install emission controls for all new plants built after 1975. In 1979, further legislation was passed to require scrubbing and emission control even on low sulphur fuels. But existing power plants are not subject to the same requirements. The need for major action to control emissions from these older plants was stated in an address by Environmental Protection Agency Administrator Douglas M. Costle to the National Association of Regulatory Utility Commissioners meeting in Atlanta, Ga. in December 1979.

In an address to the Air Pollution Control Association in Montreal in June, 1980 Mr. Costle stated:
"We all know that many of our older industrial plants — particularly power plants — are either minimally controlled or not controlled at all. New plants are being built clean. Indeed, if we could afford to wait 30 to 40 years, emissions would inevitably drop as old plants are replaced by new. It should be clear to anyone that, environmentally, we cannot afford to wait that long. Today, retirement schedules on older plants are being stretched out, not shortened. In the meantime, the industrial base continues to grow and, with it, the amount of acid deposition."

The U.S. EPA's air pollution projections indicate nitrogen oxide emissions in that country will increase by approximately 50 per cent by the year 2000. Currently, U.S. NOx emissions nearly equal SO_2 emissions, and are expected to surpass SO_2 emissions. (FIG. 12)

Major Man-Made Sources of SO_2 and NO_x (million of short tons per annum)*

Sulphur Emissions (SO_2)

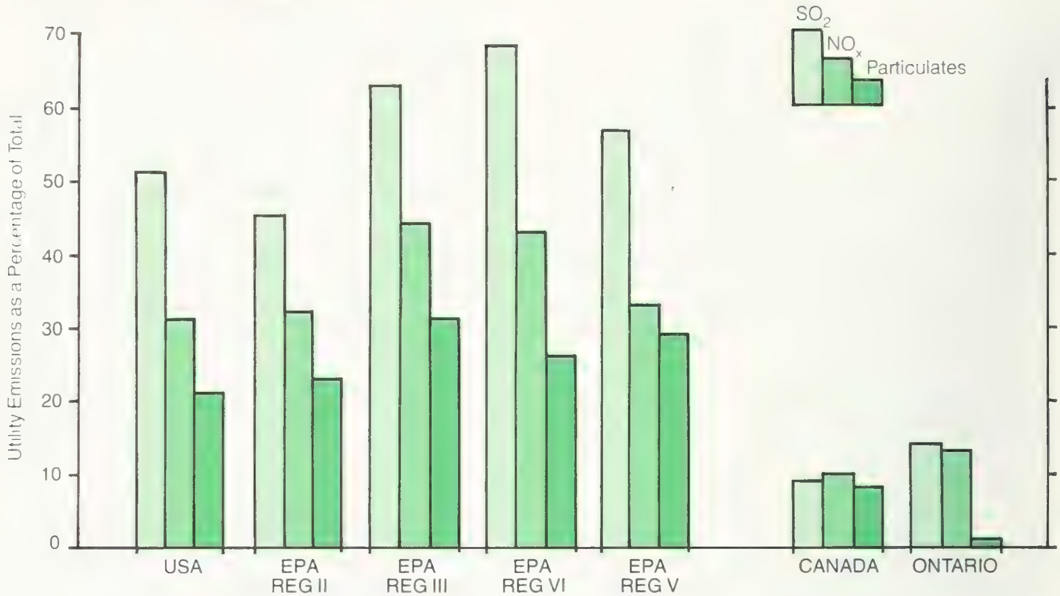
Total		Electrical Utilities		Non-Ferrous Smelters		Other-Mainly Industrial	
U.S.	Can.	U.S.	Can.	U.S.	Can.	U.S.	Can
28.5	5.5	18.6	0.7	2.8	2.4	7.1	2.4
34.0		19.3		5.2		9.5	

Nitrogen Emissions (NO_x)

Total		Electrical Utilities		Transportation		Other Combustion	
U.S.	Can.	U.S.	Can.	U.S.	Can.	U.S.	Can
24.4	2.1	6.8	0.2	10.9	1.3	6.7	0.6
26.5		7.0		12.2		7.3	

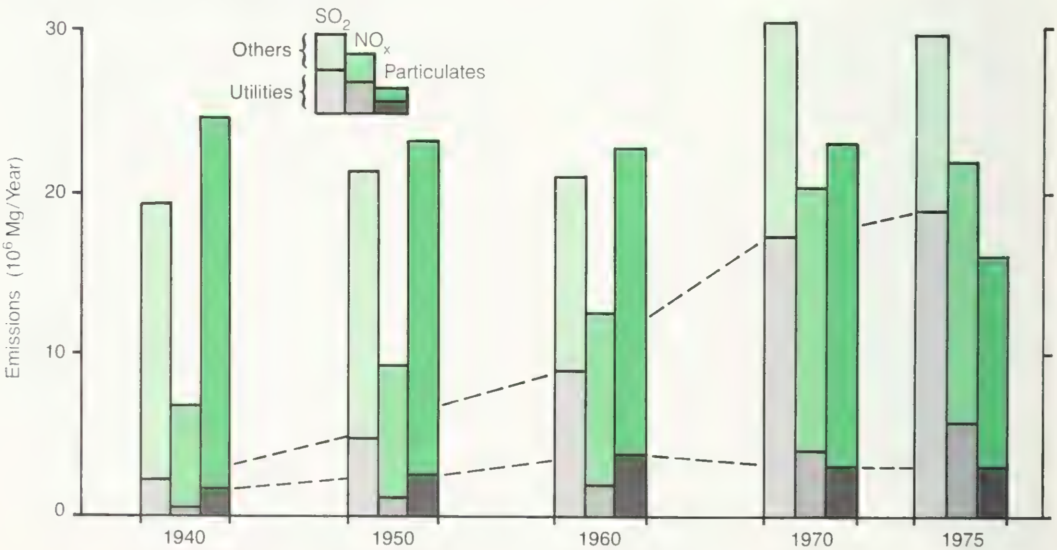
*Source of Estimates (1975) Canada-U.S. Research Consultation Group Report October 1979

FIG. 10
Relative Importance of 1974-1975 Utility Emissions by Region



Source: "Acid Precipitation: An Emission Perspective" CTS-07165-1, Environmental Protection Dept., Ontario Hydro

FIG. 11
Historical Trends in USA Emissions



Source: "Acid Precipitation: An Emission Perspective" CTS-07165-1, Environmental Protection Dept., Ontario Hydro

Burning coal produces more NOx than burning oil or gas. An EPA research report, published February 1980, estimates that by 1985 stationary sources of NOx will account for 70 per cent of U.S. man-made NOx emissions — an exceedingly large increase over current stationary sources — which EPA attributes to the growing trend toward using coal for electrical generating stations and industrial boilers.

U.S. President Carter's proposed $10 billion plan to help electric utilities which currently burn oil or gas convert to other fuels, principally coal, will exacerbate the acid rain problem in New England and eastern Canada. Under the President's proposal, the government would provide $3.6 billion in grants over 10 years to help 80 specifically designated power plants to convert to coal; another $6 billion to aid utilities to reduce their oil and gas use; and the remaining $400 million to help reduce emissions that contribute to acid rain.

Because of the potential for transboundary damage, Canada opposes conversion to coal-fired utility plants which are exempt from U.S. federal regulations. From Ontario's point of view, these conversions would compound the problem of acid rain associated with the grandfather clause in the U.S. Clean Air Act, which protects existing plants from the provision of the Act. The conversion of these older U.S. utilities to coal is anticipated to increase total U.S. SO_2 emissions by 16 per cent.

Ontario Premier William G. Davis speaking in Dallas, Texas on April 8, 1980, addressed this issue firmly:

"We do not believe massive additional reliance on coal, using old technology, is an acceptable option to help electric utilities reduce their use of oil and natural gas. Consequently, we are frankly alarmed by the decision . . . of your federal government to proceed with legislation to facilitate the conversion to coal of 107 electric utility plants, without adequate environmental protection.*

The 'acid rain' this program would produce will seriously aggravate one of the most grave and indisputable environmental challenges on our continent.

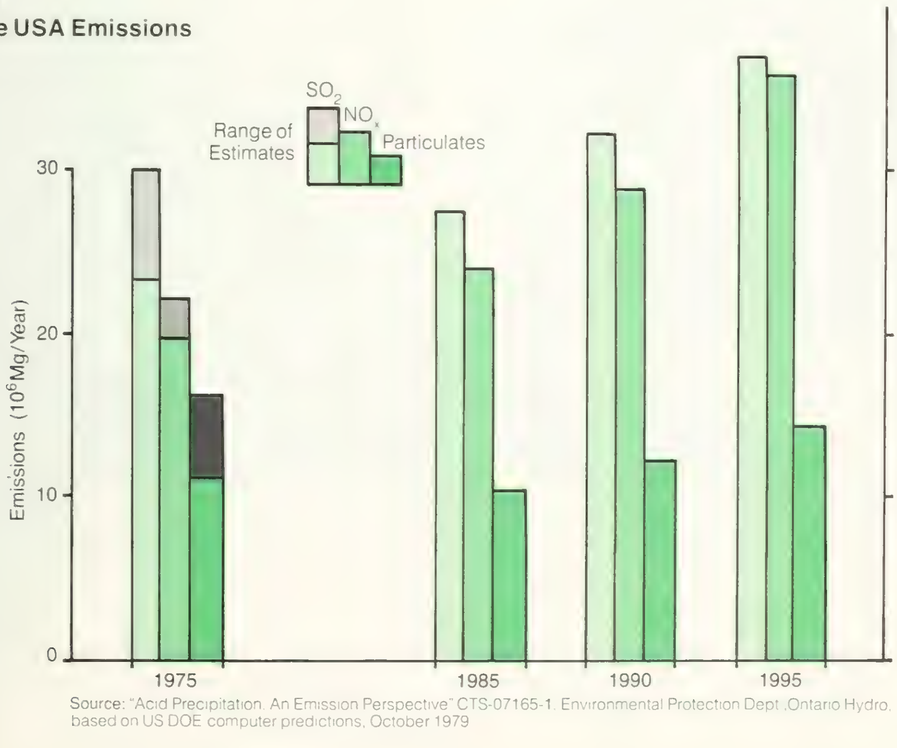
Without seeking to impose our domestic laws or methods of operation on other jurisdictions, we would nevertheless suggest that the United States should consider diversifying its energy supply systems to a greater extent, seeking alternative energy sources which in total will have a less severe impact on the environment than a continued reliance on fossil-fuelled generation, which apparently includes massive conversion to coal.

Extensive representations have been made to your national government and others will be made to express our concern

Most of the plants specifically targeted for conversion are in the northeast and represent an immense environmental risk to literally thousands of Canadian lakes and rivers."

*The projected 107 electric utility plants to receive U.S. federal aid for conversion to coal was reduced to 80.

FIG. 12
Future USA Emissions



Source: "Acid Precipitation. An Emission Perspective" CTS-07165-1. Environmental Protection Dept., Ontario Hydro. based on US DOE computer predictions, October 1979

Ontario Hydro and INCO Abatement Programs

Ontario Hydro utilities produce electrical power for the Province utilizing nuclear and fossil fuels and hydralic energy in roughly equal proportion, with each accounting for about one-third of total power production. (FIG. 13)

Since 1970, the generation of electricity from coal in the Province has increased substantially and this has led to an increase in SO_2, as well as NOx emissions, from Ontario Hydro facilities. These increased emissions are expected to peak in 1981-82, then to decline as nuclear fuel provides an increasing portion of Ontario Hydro's total energy supply. Current combined SO_2 and NOx emissions from Ontario Hydro facilities total 0.5 million tons. In 1979, these emissions accounted for about 30 per cent of Ontario emissions of SO_2 and 20 per cent of NOx emissions. (FIG. 14)

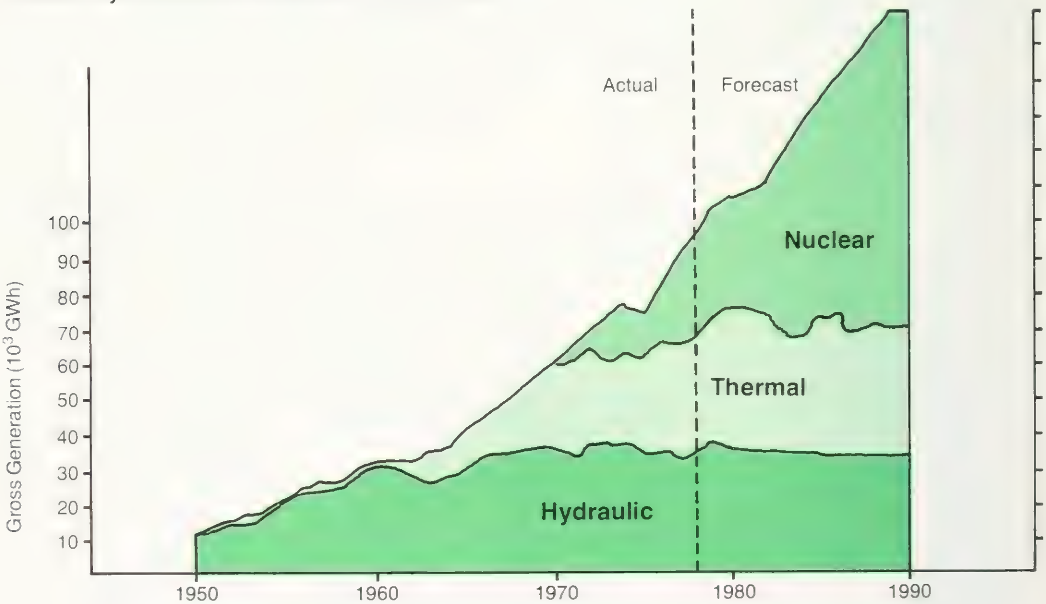
Hydro's output of SO_2 per kilowatt hour from coal production has decreased steadily over the past decade as a result of cleaner fuels and more efficient operation.

A strong factor in controlling SO_2 emissions is Ontario Hydro's established practice of demanding washed coal from all suppliers. This measure alone reduces sulphur levels by 15 to 20 per cent. Another general policy is Hydro's encouragement of the use of low sulphur fuels, and the blending of Western Canada bituminous coal supplies which are low in sulphur content, with U.S. supplies to reduce SO_2 emissions. In addition, most of Hydro's coal burning plants operate under Environment Ontario control programs related to local air quality and the prevention of air pollution episodes under the provincial government's Air Pollution Index (API) and Alert Program.

There are other options for electricity generation — alternative energy sources such as nuclear plants, greater hydro capacity generated through a national power grid, garbage as a fuel additive or supplement, solar energy and wind power. Ontario is investigating the potential for using garbage to replace up to 40 per cent of the fuel now used in cement kilns, and the Ministry of Energy is looking at further possible applications of this energy source.

These options are not available for ore smelting operations, though hydrometallurgy and other advanced abatement technologies are available.

FIG. 13
Ontario Hydro Gross Generation-1950-1990



Source: "Acid Precipitation: An Emission Perspective" CTS-07165-1, Environmental Protection Dept., Ontario Hydro

FIG. 14
Ontario Hydro SO_2 and NO_x Emissions for 1979

Fossil Fuel Stations	SO_2(Mg/Year)	NO_x*(Mg/Year)
Windsor	31	10
Thunder Bay	10,033	1,059
R.L. Hearn	10,191	4,291
Lakeview	91,347	13,785
Lambton	160,249	12,864
Nanticoke	155,078	28,650
Lennox	10,012	992
TOTALS	436,941	61,651
	(480,000)**	(68,000)**

*NO_x Expressed as NO ** Short Tons/Year
1980: Predicted Levels will be down slightly

Non-Ferrous Smelting— Sudbury

INCO Limited, the world's largest nickel producer, which mines ore with heavy sulphur content at its Sudbury mining and smelting complex, is the continent's largest single source of SO_2 emissions. It accounted for 3.9 per cent (1.32 million short tons) of total North American emissions in 1975, according to the Canada-U.S. Research Group's report.

Since INCO's emissions of NOx are negligible, the company accounted for 2.2 per cent of the total combined Canada and U.S. emissions of SO_2 and NOx, the major percursors of acid rain.

INCO has cut its total SO_2 production in its Sudbury operations by over 40 per cent since 1969 by the production of sulphuric acid. This reduction, coupled with "superstack" dispersion since 1972, has produced substantial air quality improvement in the local Sudbury area, which at that time was the primary objective.

From the outset, the tall stack approach was identified as an interim pollution control measure and not as a final step in abatement at the company's Sudbury facilities.

As a first planned step aimed at reducing current SO_2 emissions in the Province, Environment Ontario Minister Harry Parrott announced on May 1, 1980 the government's intention to establish new control measures on INCO. The proposed program would bring about a reduction of INCO's emissions of SO_2 from the level of 3,600 tons permitted in a former Control Order to 2,500 as a first step, and 1,950 tons per day during 1983. The new order also instructs the company to complete a study by December 1981 as to how it will reduce emissions to the lowest possible level after 1982.

Another part of Environment Ontario's abatement program for this Sudbury smelting complex entailed the establishment of an Ontario-Canada Task Force to investigate all air pollution abatement technical options, as well as the socio-economic implications, for both INCO and Falconbridge Nickel Mines, with the objective of reducing emissions to minimal levels. The working committee of this joint Task Force includes representatives from Ontario and federal environment ministries, the Ontario Ministry of Natural Resources, the federal Department of Energy, Mines and Resources and non-government scientific representatives.

Three reports compiled by Environment Ontario, released May 27, 1980, which provide recent field analyses of acidic precipitation affecting the Muskoka-Haliburton and Sudbury areas of the Province, have been referred to this Task Force. The studies are significant in evaluating the emission effects of the Sudbury smelting complex on the immediate Sudbury area as well as on the Muskoka-Haliburton lakes, and underline the need for international abatement to deal with the long-range transport of contaminants.

Abstracts of the three reports and their findings are outlined in Appendix "A" (page 24).

Environment Ontario staff collect containers from automatically operated "double bucket" collector designed to collect wet and dry deposition of acidic pollutants. Samples at over 30 sites across the Province are collected monthly for laboratory analysis

ONTARIO'S ACTION TOWARD SOLUTIONS

Environment Ontario's Air Monitoring Program

Since 1968, Ontario's Environment agency has been responsible for monitoring the air of the Province, for identifying sources of undesirable emissions and for reducing those emissions to preserve environmental quality. The Ministry is also responsible for ensuring that potential emissions from new sources are adequately controlled before industrial, utility or mining operations begin.

The Ontario Government began the establishment of a Province-wide network of air quality monitoring instruments in 1968, which has been expanded over the years. The network now consists of more than 1,400 instruments which measure 30 contaminants, including SO_2 and NOx. This network coupled with special mobile monitoring units have provided Environment Ontario with the capability to measure most of the chemicals present in the atmosphere in trace amounts. The monitoring system has thus enabled the Ministry to chart its progress in controlling air pollution.

Under the Ministry's program of air pollution control, industry in the Province has spent or committed more that $1 billion for air pollution abatement. This has resulted in great improvement in the air quality of Ontario cities.

Since 1970, SO_2 levels in downtown Toronto have been reduced by approximately 90 per cent — from an average of 0.071 ppm to 0.008 ppm in 1979. Carbon monoxide decreased from an average of 2.5 ppm in 1970 to 1.5 ppm in 1979, a 40 per cent improvement. Suspended particulate levels have dropped 50 per cent in Toronto, and have been lowered in most communities by 50 per cent and more.

The air quality improvement was achieved mainly by the abatement of emissions, for example SO_2 emissions in Metro Toronto were decreased from 227,000 tons in 1972 to 153,000 tons in 1978.

In other industrial centres in Ontario, such as Hamilton, Windsor, London, Ottawa and Cornwall, SO_2 levels have been reduced from 30 to more than 60 per cent.

Across the Province, community-oriented abatement has reduced SO_2 loadings from almost 3 million tons in 1972 to 2.2 million tons in 1977* — a reduction of 27 per cent despite increased population and industrial growth. This is a straight reduction of total SO_2 production, completely apart from localized improvements resulting from higher stacks and wider dilution.

This successful reduction of pollutants is also a consequence of Ontario's practice of requiring regulatory approvals for each industry planning to build or expand.

Nitrogen oxide emissions from automobiles have also been reduced. The control of nitrogen oxides from automotive sources was introduced by the Canadian government in 1973. These controls have reduced emissions from individual vehicles by approximately 30 per cent (from 4.5 grams/mile to 3 grams/mile). However, the gradual reduction achieved by new cars with control devices replacing older cars, was offset to an extent by an increase in the number of vehicles. Therefore, the overall reduction in nitrogen oxides emissions from 1973 to 1979 was 11 per cent (from 175,000 tons/year in 1973 to 155,000 tons/year in 1979).

Also, Metro Toronto's public transportation system which serves more than one-quarter of the population of the Province, is largely electrically operated by streetcars, subway trains and trolley buses which do not pollute the air.

Environment Ontario has been dealing with SO_2 and NOx as pollutants in their own right, concerned with their local and community effects. It did not at first deal with them as constituents of acidic precipitation — acid rain which is now defined as a long-term and long-range problem with effects on a continental, even global scale. Tha accumulation of SO_2 and NOx cause damage even though conventional air quality criteria are not exceeded.

The severity of the problem of acid rain in Ontario became apparent when Environment Ontario, working with the Ministries of Housing and Natural Resources, began to monitor the impact of cottage development on lakes in the Muskoka/Haliburton resort areas in 1975, in the context of the Lakeshore Capacity Studies. While examining material imput to the lakes from all sources, including the atmospheric contribution, it was discovered that atmospheric input on average was much more acidic than anticipated.

Ontario's Commitment and Strategy

Ontario in the fiscal year 1980-81 appropriated approximately $5 million for acid rain projects through its ministries and agencies.

Environment Ontario, the lead ministry, required approximately $3.5 million for its 1980-81 program.

In the fiscal year ending March 31, 1980, Environment Ontario spent $2 million in research activities to determine acidic deposition and to develop abatement strategy.

Ontario scientific projects and studies are outlined in the sections entitled "Aquatic and Terrestrial Effects and Studies" (pages 17-22).

Ontario's commitment and strategy to hasten abatement action and to help reach a formal accord for U.S.-Canadian co-ordinated policy was outlined by Environment Ontario Minister Harry Parrott at a meeting with Canadian and U.S. environment ministers and officials on January 18, 1980.

*In 1979, SO_2 loadings were reduced to an estimated 1.65 million tons, to show a decrease of over 40 per cent since 1972. However, the 1977 figure is used because INCO limited, Ontario's largest single source of SO_2 emissions, was shut down for the period July 17 to August 27, 1978, and later closed by an 8½-month labour strike from September 15, 1978 through June 4, 1979. Since production resumed in June 1979 INCO has kept emissions to approximately 2,600 tons per day (0.95 million tons per annum) mainly due to reduced market demand. The Falconbridge nickel smelter was also shut down between July 1 and August 21, 1978. For data during these periods, see Appendix 'A' — reports compiled by Environment Ontario providing field analysis studies of acidic precipitation in the Sudbury and Muskoka/Haliburton areas.

"In Ontario, we have undertaken measures to provide the Ontario Government with knowledge which it must have to develop a sound abatement strategy:

- *—We are continuing to identify and assess acid loadings in those Ontario lakes most susceptible to acidification.*
- *—We are refining our predictive modelling techniques to better assess the social and economic effects of various control strategies.*
- *—We are actively considering possible interim remedial measures which can be employed to protect the sensitive lakes.*

We believe—with others—that we must develop and then employ reliable control technology on both existing and new sources, initially, where the greatest environmental benefits will result. While seeking this better technology, other options presently being considered include a combination of the following:

(1) low sulphur coal
(2) hydrometallurgy
(3) coal gasification
(4) coal scrubbing—reducing the sulphur by washing
(5) acid plants—removing SO_2 and converting it to sulphuric acid for various uses."

Dr. Parrott stated that both countries recognize that the problem on either side is different and that controls will have to be made specific to the types of sources on either side. This results from a different mix of problems in each country requiring different solutions.

"Acid rain, already at levels of widespread concern and destruction, appears to our experts to remain rampant, unless we initiate more immediate abatement action.

I am convinced, if we are to seriously address the problem of acid rain, that all jurisdictions must be willing to assess emissions from **existing** *plants, many of which were built at a time when governments, industry and the public were less knowledgeable and concerned about environmental matters. We must also assess legislation which may perpetuate the problem through grandfather clauses which exempt existing sources and penalize new projects which may be more environmentally secure.*

*If we are to keep on schedule with the crucial period of abatement which must take place over the next ten years—**and I am now concerned about saving thousands of Ontario lakes which are vulnerable**—our international abatement measures must focus on attacking* **existing** *sources of pollution as well as research and future prevention.*

It is imperative that the United States and Canada reach an accord on what is to be done. But such an accord must be negotiated on the basis of strength from both sides. We in Ontario aim for an international agreement soon. But this agreement must be flexible enough to take advantage of new knowledge resulting from research as it evolves. This is especially true in the area of new abatement technology.

Recognizing that we both operate under different constitutional and administrative structures, and that there is a different mix of problems in each country, the solutions will of necessity be different in each country. Whatever strategies are adopted to achieve our common goal, they must be rigorously enforced by each jurisdiction in a consistent manner.

I again emphasize that Ontario is prepared to enforce the necessary controls in concert with control measures in other jurisdictions. And we are also prepared to act singly and in advance of other jurisdictions in the fight against acid rain."

Interim and Ultimate Solutions —Socio-Economic Implications

Resolution of the problems caused by acidic precipitation poses a certain dilemma to society. On the one hand, there are risks that actions taken will be too late or insufficient. On the other, there is the risk that actions taken in haste will be unduly costly, disruptive to the economy, or ineffective.

There are no **verified** estimates of either the magnitude of the damages and effects caused by acidic precipitation, or the costs of abatement of sources inside or outside the Province.

For these reasons, Dr. Parrott cautioned that while Ontario is moving ahead to take interim abatement action so that no crucial time is lost, it must first be determined that costly long-term abatement actions can be effective.

"In the long-term we must weigh the efficiency of various abatement methods against the actual problem. The cost of such abatement runs into billions of dollars, and cannot be entered into lightly, without firm evidence that they will successfully perform."

Ontario is refining its predictive modelling and deposition studies to properly assess the economic and social effects of various control strategies. At the same time, attention is being given to the development of new and more efficient control technology.

In order to develop estimates of the benefits to be derived from abatement actions, as well as the costs of the control programs, the Province has established an Acid Precipitation Socio-Economic Impact Committee whose members represent the Ontario Ministries of Environment (lead ministry), Natural Resources, Industry and Tourism, Energy, Agriculture and Food, and Treasury and Economics.

One of the fundamental economic questions concerns how much manpower, money and effort should be devoted to combating acid precipitation. Some individuals argue that governments and those who cause the pollution should stop it at any cost. However, individuals and society at large obtain essential benefits from power plants, smelting operations, factories and transportation vehicles, all of which are the precursors of acid rain. If people wish to retain the benefits and amenities provided by these products and activities, and at the same time preserve the environment, they may have to accept higher prices for them.

Realistic Levels of Abatement

While total abatement of sources would solve the problem, it must be accepted that North American society will be using large amounts of fossil fuels for many years to come, despite the newer options of nuclear plants, solar energy and wind power. It must also be accepted that it is most unlikely that technology could reduce emissions of sulphur and nitrogen oxides to zero. Therefore, the abatement programs applied to new and existing sources must define some specific amount which can be realistically achieved by technology and be effective in protecting the environment. We must determine in quantitative terms how much acid loading the environment can safely withstand so that the minimum levels of abatement can be defined.

There are tremendous technological and economic differences between the attainment of 50 per cent abatement of sources and 80 per cent, 90 per cent or 95 per cent. Research is needed to define what abatement level is needed.

Consequently, the studies to determine the effects of atmospheric deposition on aquatic and terrestrial ecosystems in Ontario are designed to determine the extent of problems in the Province, and the rates of change of water quality and other effects which are needed to design and support the abatement program.

One important issue under study by the Socio-Economic Impact Committee is tourism and sports fishing, important industries to Ontario and Canada. While expenditures for products and services associated with tourist activities do not directly measure the value of the benefits of reducing acid precipitation, these expenditures are important to regional economies. Failure to curtain acidic precipitation could severly affect tourism related to sports fishing.

While most of the costs of the various abatement or rehabilitation programs can be expressed in dollars, many of the social and environmental consequences of these activities can only be measured in intangible physical units or in dollar value estimates which are often open to dispute. Nevertheless, a systematic compilation of the relevant social and environmental consequences of each feasible abatement or rehabilitation program will be of great help in deciding what needs to be allocated to the problem.

Equity and the Distribution of Costs and Benefits

Another important economic issue concerns the distribution of the effects of acid rain and of the costs and benefits of its control. Questions of equity will have to be resolved through negotiations among provinces, states and federal governments. It is necessary for the negotiators to have clear information about the various options and about the magnitudes of the costs and benefits involved.

Finally, wide ranging public consultation and debate will be constructive and necessary to political decision-making. It is as important for the public to be informed on this issue as it is for governments to generate and disseminate the relevant information.

A May 1980 report on acid rain by the LRTAP Control Strategies Program Office of Environment Canada concludes with the statement:

> "At present, the direct evidence required to ascertain unequivocally that the North American ecosystem is being severely damaged by the long-range transport of air pollution and acidic precipitation is not available and may not be for several years. Effects are cumulative and elusive, but to wait long enough to obtain, say, a clearly demonstrated effect could mean that a stage of site degradation has been reached that would be impossible to reverse."

In July 1980, 2,000 cottagers attended Environment Ontario's biggest ever open house at the Ministry's field laboratory near Dorset, to tour the laboratory, view field equipment and question scientists about the effects of acid rain in lakes of the Muskoka/Haliburton region

AQUATIC AND TERRESTRIAL SCIENTIFIC ACTIVITIES

Aquatic Studies in Ontario

Current aquatic studies in Ontario are designed to determine the extent of problems in the Province, and the rate of change of water quality, information vitally needed to design and support the abatement program.

Aquatic studies begin by measuring as accurately as possible all of the materials being deposited in each particular watershed from the atmosphere. A variety of collectors are used to obtain this information. Some are designed to collect only rainfall and have a moisture sensitive control device which opens the lid of the collector only while it is raining. Other collectors are open at all times so they collect both rain and any material that settles from the air — so-called "dry deposition". Still other collectors are designed to measure snowfall. In all cases the total amount of water, acids, minerals, and other materials that are being deposited are measured. In total, about 20 constituents are measured in rain and snowfall.

Meteorological data are collected to assist in calculating evaporation rates, to determine seasonal precipitation, prevailing winds, and to trace storm trajectories and origin.

All of the streams entering and leaving the study lakes are fitted with weirs. The amount of water flowing is continuously recorded as it goes through the calibrated notch. Water samples are collected frequently for chemical analysis. This system, whereby all inputs and outputs are carefully and precisely quantified, is called a "calibrated watershed".(FIG. 15)

Computers are used to combine the water flow and chemical data to measure the amounts of acids and other materials entering and leaving the lakes. The influence of the trees and soils on the chemical composition of the water is made evident by comparing the runoff water quality to the rain and snow quality. Direct measurements are made on the chemical nature of the soils. This process is called "materials budgeting" and the information indicates whether or not water quality is changing and how fast, what kinds of changes are taking place and what is likely to result from trends in both the near and long-term future.

The study lakes automatically become the monitors of the effectiveness of the abatement programs as acid loadings are reduced.

Cumulative Aquatic Effects

The amount of acid falling as acid rain is quite small with each rainfall, but its cumulative long-term effects, as well as its "shock" effects on aquatic life at the time of spring runoff, are what concern scientists.

In areas with alkaline soils or limestone deposits, such as the Great Lakes, total loading of acid rain on an annual basis does not pose a problem since the acid can be safely neutralized for indefinite periods. Though these lakes are not threatened as whole bodies, aquatic life in the nearshore spawning areas and tributary streams, which are much shallower, can be severely affected in the spring by the "shock" loading of acidic snow as it melts — "spring runoff".(FIG. 16) This condition applies, for example, to the nearshore spawning areas and streams of Lake Huron, even though the lake has an annual mean alkaline pH of about 8.2.

FIG. 15

Fitted Weir in Calibrated Watershed.

A weir is fitted into streams which enter or leave study lakes to continuously record the amount of water flowing through the calibrated notch. The system is known as a "calibrated watershed

Environment Ontario scientist collects water sample [illegible] weir on a Haliburton stream. Hut on bank is known as a "stilling well" which houses a water [illegible] measure stream flow on a continuous basis

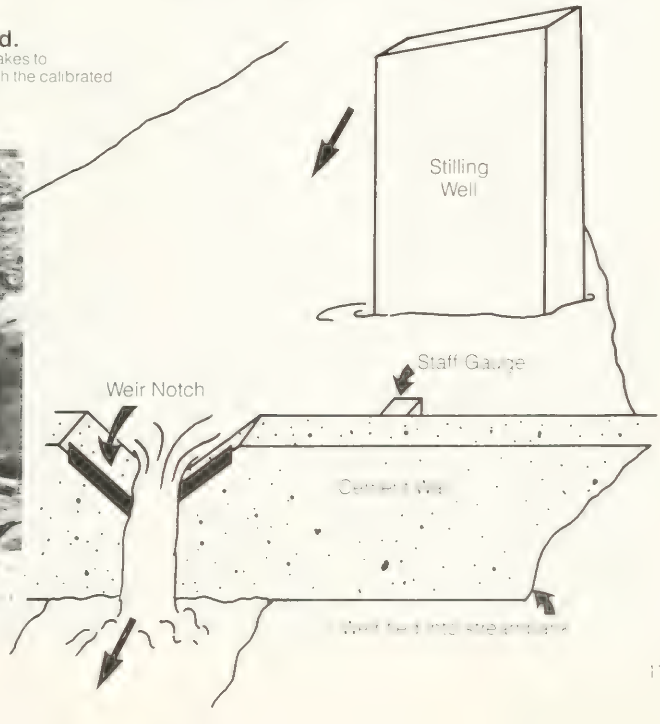
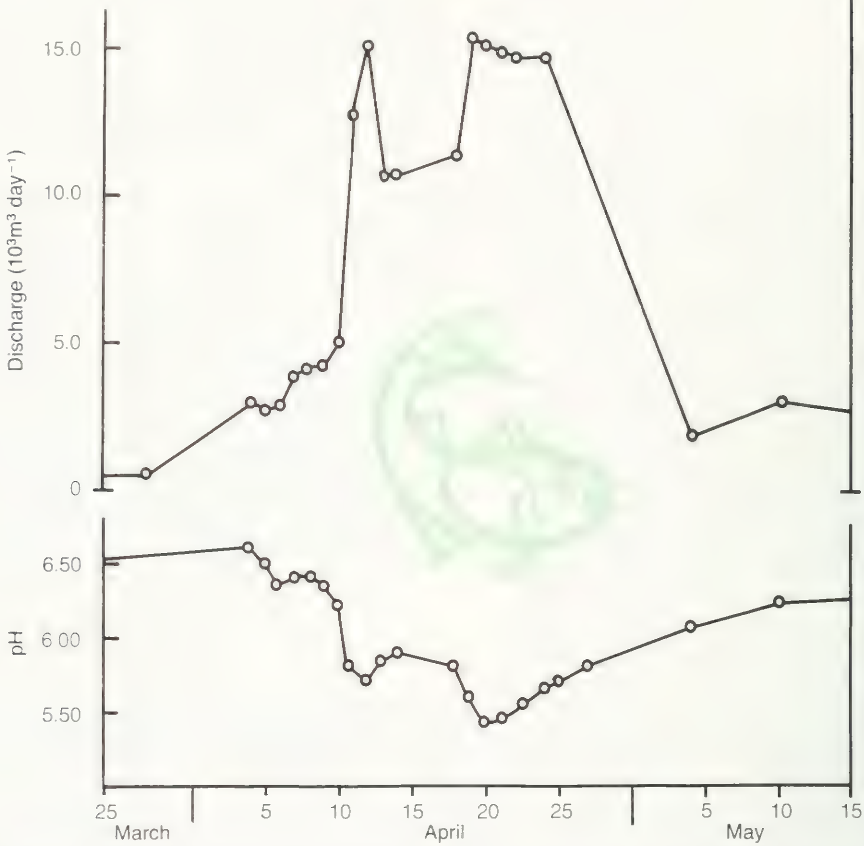


FIG. 16
"Spring pH Depression" of a Stream

Graph illustrating "spring pH depression" in one of the six inflowing streams to Harp Lake, a study lake in Muskoka. As the spring runoff increases the amount of water, the acidic melted snow causes the stream pH to drop, producing severe chemical "shock" effects on aquatic life



As the acid rain is neutralized, some soil and rock material is dissolved. If the acid rain lands on limestone, the runoff will contain calcium sulphate and calcium nitrate — both quite harmless substances.

Precambrian rock can slowly neutralize acid rain but instead of calcium, it releases aluminum, manganese, iron, and other metals which can build up to concentrations which are toxic to fish and other forms of aquatic life.

In areas of Precambrian rock and little soil cover, which is the situation in much of northern Ontario, there is not enough buffering capacity to neutralize even small amounts of acid falling on the soil. As a result, the runoff water is acidic.

The effect shows up at different times in streams entering the same lake because the process of acidification of runoff is quite irregular. For example, a light acid rain may be fully neutralized while the runoff during a heavy rain on the same watershed will not have time to be neutralized so a "pulse" of acidic water will move down the stream and into the lake. The stream will have normal pH values shortly after the surge of water passes. But the aquatic organisms living in the stream will have been subjected to a very severe chemical shock.

Acids falling in snow accumulate during the winter. When the snow melts there is a relatively sudden release of a large amount of acids in the runoff. The soils are usually frozen and there is very little chance for the acids to be neutralized. The result is a phenomenon known as the "spring pH depression".

For periods of several weeks streams can become very acidic. Their flows combine with melting snow and ice on the lake itself, and acidify the entire surface layer of the lake. As the lake water mixes and is brought into contact with sediments, the acid can be eventually neutralized and the lake can have normal pH values by June or July.

Some aquatic organisms — such as recently hatched spawn or offspring (known as "fish fry") of sports fish (e.g. trout, bass and pickerel) — cannot survive the shock of exposure to acid water, or acidic water containing high concentrations of metals. Consequently, in both acid stressed lakes and fully acidified lakes there is a major disruption, or complete destruction, of the biological community.

The spring pH depression is the most damaging feature of an acid stressed lake but the severity varies from year to year according to spring weather conditions.

Large fish can generally survive so that dead fish are rarely seen floating in the lakes. Fish fry of sensitive species may by killed one year but have a high survival rate the next. Therefore, the fish populations in acid stressed lakes are characterized by the absence of fish of certain ages, with older and younger fish being present. Mercury concentrations may also increase in the fish which do survive. As the lake and watershed are more and more damaged by acid rain, the spring pH depression is consistently severe. The fry of the sensitive species will be killed every year so that the existing population dies out from old age and predation. Several decades may pass from the onset of some damage to the fishery until its eventual demise.

If acid rain continues, all of the readily available neutralizing capacity of the rocks, soils and sediments may be consumed and the streams and lakes become acidic all year long. It can take many decades for a lake to become fully acidified.

When a lake becomes so acidic that the pH is below 5.0 at all times of the year, few fish species or other aquatic life survive.

It is reasonable to assume that an acidic lake will eventually recover if the acid loadings are eliminated or reduced to very low levels. The time required for this is not known. In Precambrian areas, only the surface of the rocks interact with rainfall and runoff so that new surface material is constantly being exposed by weathering. If the acidic loadings are removed the new material will establish the same pH in the runoff as prevailed before acidic precipitation occurred. Return to normal conditions will certainly take a period of years but no accurate estimates can be given. If a lake has been acidic long enough for most aquatic organisms to die, restocking would be needed.

Research and analysis are carried out at Environment Ontario's main laboratory in Rexdale, one of the most sophisticated in North America

Aquatic Life Analyzed

Since the main concern about acid rain at this time is its effect on aquatic life, very detailed measurements must be made of the algae, zooplankton and fish within the study lakes. The absolute numbers and species of zooplankton are counted and their stomach contents microscopically examined in Environment Ontario laboratories to determine what they eat. This information may be critical in attempts to modify fisheries management schemes to assist fish populations in coping with the problem. Even if the water quality is acceptable to some species of fish, a serious disruption of the food chain could pose problems for the fish.

Trap nets are placed in the study lakes to capture the fish alive. Every fish is measured, weighed and species and sex recorded. A coded tag is put on each fish released back to the water. When the netting process is repeated at a later time, the numbers of tags recovered can be used to accurately determine the total numbers of all species of fish present in the lake. Thousands of fish must be handled in this painstaking and time-consuming procedure but it is the only way that subtle changes in the fish population can be observed.

All chemical and biological results are combined to produce estimates of present damage to the ecosystem, to establish the reasons for any observed changes and, most important to construct graphs indicating likely changes in the future, and to determine the minimum reduction in acid inputs required to protect the environment.

There are six lakes currently under this extensive study in the Muskoka-Haliburton area. There are an additional 15 lakes receiving slightly less intensive work. In future, additional study lakes will be added for specific purposes.

A temporary field laboratory has been operated for several years near Dorset, Ontario, and has been replaced by a permanent lake study facility which serves as the Province's headquarters to co-ordinate and integrate all LRTAP field studies.

The study lakes have been selected in one of the most sensitive areas to be affected by acid loadings. A large part of the information gathered from these studies can be extrapolated, or extended, to other susceptible lakes which may be affected to a lesser and/or slower degree than the main study area.

It is known that the alkalinity of the lake water is the single most important factor in determining a lake's sensitivity, or its ability to neutralize acidic inputs. While the intensive lake studies are under way, alkalinity data are being collected on a large number of lakes across the Province.

The Province has about 250,000 lakes. Even if estimates of alkalinity are made in several thousand lakes, there will still be other thousands of lakes for which data will not be available. However, results from the study lakes will indicate what damage to expect for any given lake measured for alkalinity. Therefore, reasonably accurate estimates can be made of total damage in the lakes when only a small amount of chemical and geological data are available.

Liming of Lakes

Acid rain damages aquatic life in lakes and streams only in areas where there are very little capacity in the soils and rock to neutralize the acid. Could not a neutralizing material be added to the lakes and streams for at least the time it takes for the abatement program to take effect?

The major method of artificial maintenance of susceptible water bodies has been to add slaked lime and/or limestone to affected lakes, in an attempt to restore their buffering capacity. This process of adding a neutralizing agent is called "liming".

The amount of lime or limestone needed is generally about 50 lbs. per surface acre per year, which means that several tons of material are needed for even small lakes.

Biological Effects on Fish of Low pH Waters

pH	Effect
6.5 or less	Continued exposure results in significant reductions in egg hatchability and growth in brook trout.—*Menendez, 1976*
6.0	Coupled with high CO_2 concentrations pH's below 6.0 can adversely affect certain trout species.—*Lloyd and Jordan, 1964*
5.5-6.0	Rainbow trout do not occur. Small populations of relatively few fish species found. Fathead minnow spawning reduced. Molluscs rare. —*EPA, 1972*
5.5	Declines in a salmonid fishery can be expected.—*Jensen and Snekvik, 1972*
5.0-5.5	Very restricted fish populations but not lethal unless CO_2 is high. May be lethal to eggs and larvae. Prevents spawning of fathead minnow. Lethal to some mayflies. Bacterial species diversity reduced.—*EPA, 1972, Scheider et al, 1975*
5.0	Tolerable lower limit for most fish.—*Doudoroff and Katz, 1950, McKee and Wolf, 1963*
4.5-5.0	No viable fishery can be maintained. Lethal to eggs and fry of salmonids. Benthic fauna restricted.—*EPA, 1972*
4.5	Flagfish reproduction inhibited and general activity of adults reduced.—*EPA, 1972*
4.0-4.5	Fish population limited—only a few species survive (pike). Flora restricted.—*EPA, 1972.*

–Ontario Ministry of the Environment, Extensive Monitoring of Lakes in the Greater Sudbury Area 1974-76, Ministry of the Environment (Ontario), 1978, p. 20. References shown in italic.

Since 1973, four acidified lakes in the Sudbury region have been limed by Environment Ontario as part of the Ministry's Sudbury Environmental Study. Located about ten miles from the INCO superstack, three of the lakes were small (less than 200 acres) and were fully acidic with elevated concentrations of metals, particularly copper and nickel. The lime and limestone additions were successful in returning the pH to normal values. However, while the metal concentrations decreased (they precipitate from solution at near neutral pH), they still remained at levels toxic to fish. Fish are very susceptible to water chemistry changes, and neutralization was not by itself sufficient to make the lakes suitable for aquatic life. Fortunately, the concentrations of copper and nickel are a problem only in a small number of lakes within a few miles of Sudbury.

The fourth study lake was 750 acres, located about 20 miles north of Sudbury. The pH was depressed but the lake still had some fish and heavy metal concentrations were low. The pH was restored to normal over a two-year period of time, using a total of nearly 120 tons of powdered lime and limestone. Indications are that the treatment was successful in restoration of the fishery.

New York and Sweden are also conducting liming programs and, again, indications are that fish in some acid sensitive lakes can be protected by this technique.

One positive initial observation, in both Ontario and Sweden, is that the mercury concentrations in fish do not increase if the lake has been limed even though the acidic precipitation and acidic runoff from the watershed both continue. This is a particularly important finding in protecting a lake which provides sports fishing. The results of work to date are making biologists more optimistic about liming programs.

Ontario is currently conducting a five year experimental lake liming program to determine the chemical and biological effects of adding limestone to acid-stressed lakes. Such lakes are subject to low pH conditions during snow-melt and following heavy rainfall but for most of the year the water quality is acceptable for fish and other aquatic life. These lakes still have a very complex food chain. Treating a lake with limestone doesn't return it to its "original" condition. Though the treated lakes will be more suitable for aquatic life than if left untreated, the water quality will be different from what it was before the combination of acid rain and limestone was applied. Scientists want to see how the complex food chain reacts to the new water quality conditions.

It is possible that a liming program could be used to protect important fisheries or lakes of particular historical or economic importance. While "liming" may have its place as a remedy to solve a short-term local acid rain problem, and could be a measure for "buying time", it does not by itself offer a general solution because of the difficulties of treating the large areas of Canada affected by acid rain.

Terrestrial Effects and Studies

Acidic precipitation has the potential to cause serious widespread effects on terrestrial ecosystems in certain areas of the world, such as eastern Canada (including Ontario), the northeastern U.S. and southern Sweden and Norway.

Such effects have been observed mainly under laboratory conditions and at pH levels, or acidic concentrations, well below those generally observed in the field.

In experiments using simulated acidic precipitation, a number of adverse effects have been produced in soils and vegetation. The adverse soil effects include the leaching of basic cations such as magnesium and calcium; the mobilization, or release, of soil-bound metals such as aluminum and iron; and changes in biological activity such as nitrification. In vegetation, the adverse effects observed include leaf cuticular, or surface erosion; lesions on the leaves; leaching of nutrients and reduced nitrogen-fixation. With vegetation, a paradox sometimes occurs whereby the nitrogenous portion of acidic precipitation can act as a fertilizer and stimulate plant growth.

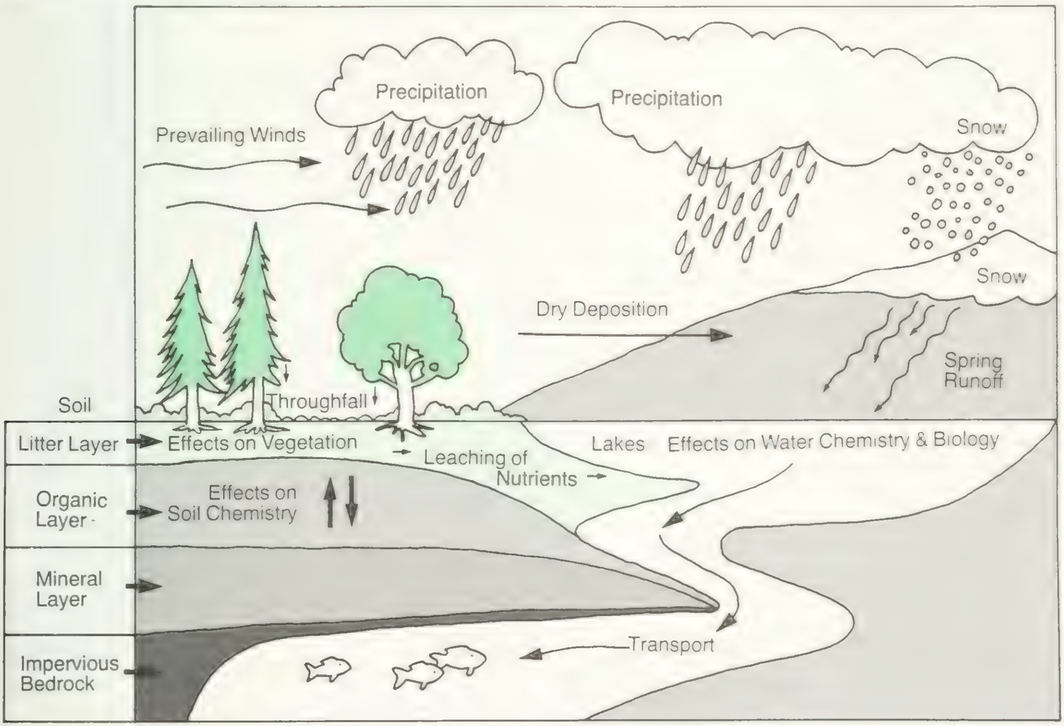
The adverse effects observed as a result of experimental exposures of soil or vegetation to acidic precipitation are difficult to extrapolate to nature. At present, there is no direct proof that any significant terrestrial effects are occurring in nature under the influence of currently-measured regional inputs of acidic substances in precipitation. The concentrations of the solutions used in the laboratory experiments are usually more acidic than those measured in normally-occurring precipitation.

With respect to forest productivity, it is possible that excessive leaching of nutrients from the soil could result in impoverished tree growth, which would therefore be harmful to Canada's competitive forest industry. However, studies to date in Ontario have not established that tree growth has been impaired, and any threat of this nature would appear to be long-term.

Reductions in forest growth have been reported in certain parts of southern Sweden, but it is difficult to attribute these lossess to acidic precipitation alone. Other environmental variables such as climate, a change of land use, site, tree age, genotype, competition from other plant species can obscure the effects caused by acidic precipitation.

Nutrient recycling is a constant natural process. The leaching of bases from forest soils is compensated for by leaf fall and root weathering of bedrock. These and other factors make it difficult to detect the effects of acidic precipitation on forests, and there is little historical data on which to base current research studies.

FIG. 17 Illustration of Terrestrial/Lake Effects



In agricultural areas, effects from acidic precipitation are not expected to pose as great a potential problem generally as in forestry, because of the continual addition of lime and fertilizers to soil in the practice of more intensive crop management.

Finally, while it may not be entirely possible to document the effects of acidic precipitation on vegetation in the field because of their subtle nature, severe effects have been documented in laboratory research. Because of the potential long-term threat that acidic precipitation poses to terrestrial ecosystems, including Ontario's vital forest industry, a program of monitoring, surveillance and experimentation is under way in the Province.

Terrestrial Studies

Ontario studies on terrestrial effects include:

- — Determining the present status, or baseline data of soil throughout Ontario. These data will provide "point-in-time", or baseline measurements of physical and chemical characteristics of soils in various regions of Ontario to compare with future testing for any trends which may develop.
- — Determining the most vulnerable soils to acidic precipitation and their location in Ontario.
- — Determining the influence of terrestrial systems on incoming acidic precipitation and altering the rain's chemical characteristics during drainage through watersheds to receiving rivers and lakes.
- — Determining the short-term experimental effects on soils and vegetation, utilizing severe acid loadings to reduce the time span for effects to occur; and determining the long-term effects which may occur on natural forest systems.
- — Determining protective or remedial measures for the most sensitive terrestrial areas.

Buildings and Structures

There is clear evidence that acidic precipitation in this century has been responsible for the sudden rate of deterioration of ancient buildings, landmarks and statuary which are a part of man's cultural heritage. Examples are the Pantheon in Athens, St. Mark's Square in Venice and landmarks in other European capitals. Increased pollution is also hastening the deterioration of modern metal and masonry structures of all kinds, as well as painted surfaces.

A current study of aging tombstones in war veterans' cemeteries throughout the U.S. will help scientists reach a better understanding of acid rain effects on stone monuments and statuary.

Health Implications

It remains difficult to demonstrate a relationship between acid rain and human health, and up to 1980 no effects generally have been scientifically described.

Epidemiological studies have shown a relationship between the severity of health effects and the degree of air pollution as measured by concentrations of suspended particulate matter, especially sulphates and sulphur dioxide in industrial and urban settings.

It is widely known that "air pollution episodes" in the past, in other parts of the world, have caused an increase in human illness and mortality for people with respiratory problems. During these episodes, meterological conditions caused stagnation of several days duration with consequent build-up of atmospheric pollutants such as found in smog over some large industrial cities.

In Ontario, the Air Pollution Index (API) developed by the Air Resources Branch of Environment Ontario, is used as a basis for action in an alert system to control or prevent an air pollution episode which could cause health effects.

It has been suggested that the acidification of water supplies could result in increased concentrations of various metals from rock, soil or plumbing and that this might result in adverse health effects. This is unlikely to occur where water quality is controlled in treatment plants according to established standards.

With respect to drinking water in summer cottages, it is recommended that after any period of non-use, the water be run for several minutes to flush out any excess metal concentration.

Federal/Provincial Scientific Activities

For detailed information on current Federal/Provincial Scientific Activities, and working group programs contact:

The Co-ordinator
Acidic Precipitation in Ontario Study (APIOS)
Resources Division,
Ontario Ministry of the Environment

or

Information Services Branch
Ontario Ministry of the Environment
at
135 St. Clair Ave. West
Toronto, Ontario
M4V 1P5

Available to scientists...

"A Bibliography:
The Long-Range Transport of Air Pollutants and Acidic Precipitation"

Prepared jointly by the Ontario Ministry of the Environment and Atmospheric Environment Service, Environment Canada, this 95-page technical bibliography which lists scientific papers on LRTAP under authors' name and subject is available at $5 and may be obtained by mail with a cheque made payable to one of the following:

"Treasurer of Ontario"
with request addressed to:
Publications Centre, Ministry of Government Services,
5th floor, 880 Bay Street, Toronto, Ontario M7A 1N8

or

"Receiver General of Canada"
with request addressed to:
LRTAP Program Office,
Atmospheric Environment Services, Environment Canada,
4905 Dufferin Street, Downsview, Ontario M3H 5T4

The bibliography may also be obtained at the Ontario Government Bookstore, 880 Bay Street, Toronto.

Ontario Hydro to reduce SO_2 and NO_X Emissions to Meet Requirements of Environment Ontario Regulation

As well as action to decrease sulphur dioxide emissions from INCO Limited, the Ontario government has required by Regulation that Ontario Hydro substantially reduce emissions of sulphur dioxide (SO_2) and nitrogen oxide (NO_X) from its coal-fired electric generating plants.

Ontario Hydro is second only to INCO Limited, as the largest source of SO_2 within the Province and is the largest industrial source of NO_X. Its coal-fired stations (see pages 12 and 13) produce about 20 per cent of total emissions of these two pollutants in the Province, but are not large producers compared with similar sources in the United States.*

The Regulation limits total emissions of sulphur dioxide and nitrogen oxides to 450,000 metric tonnes beginning in 1985, dropping to 300,000 metric tonnes by 1990. At the same time, emissions of sulphur dioxide may not exceed 390,000 metric tonnes by 1985, and 260,000 metric tonnes by 1990 — a sulphur dioxide reduction of 43% from current levels. The power company is required to meet the established emission limits regardless of any increase in power demand or export of power.

In order to comply with the total emission reduction requirements, Ontario Hydro is considering taking such actions as the installation of two 500 megawatt scrubbers, advancing the schedule for nuclear generated electricity, purchasing more low sulphur coal, making greater use of coal washing, and installing low NO_X burners on its coal-fired stations.

In addition, Environment Ontario has examined Hydro's operating system and found that its efficiency based dispatch system of generating power is for all practical purposes synonymous with a "Least Emissions Dispatch System (L.E.D.S.)". Under Hydro's current efficiency based dispatch system, nuclear power and water generation will create the cleanest and cheapest power, and the generation of power from fossil fuels will occur on a peak load basis.

The L.E.D.S. philosophy dictates that a utility generates power from its "cleanest" plants first, and its "dirtiest" plants last. This ensures that plants with pollution control equipment are utilized fully, and not allowed to stand idle.

This program places Ontario Hydro in the forefront of acid rain pollution control in North America. Since Ontario's future expansion of electrical power will not involve any new fossil-fueled power generation, the abatement program is concerned only with existing coal-fired plants. Hydro's plants already meet all ground level ambient air requirements.

Northeastern United States and Ontario

Electrical power utilities account for the major share of acidic emissions from the United States.

With the substantial increase in the use of coal as an energy source in the United States, and the projected increases in SO_2 and NO_X emissions in the U.S. between now and the year 2000, controls are vital to the protection of our environment in Eastern Canada and the Northeastern United States. This point is made vividly by a 1980 EPA report**. It states that because of tall stacks and prevailing weather conditions, Canada receives from the U.S. two to four times as much SO_2, and 11 times as much NO_X as the U.S. gets from Canada.

Environment Ontario contends that one of the weaknesses of the U.S. situation is that U.S. regulations require only new utility plants to achieve an acceptable degree of cleanliness in sulphur dioxide emissions and only to meet local ambient air requirements. Existing U.S. legislation is, therefore, not geared to solving the acid rain problem inherent in long range transport.

Further, unlike Ontario, many existing plants in the U.S. are failing to meet existing state and federal standards and utilities are now seeking government permission to relax their pollution controls even more.

While Ontario can provide leadership in tackling its own costly abatement program, its efforts to reduce acid rain will be of little consequence unless our neighbors to the south follow our lead.

To delay means inevitable — perhaps irreversible — damage to the natural environments of Ontario, Canada and the United States.

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*In 1980, Ohio's 13 largest thermal power plants, alone, emitted more SO_2 (2.0 million tons) into the atmosphere we share than *all of Ontario's sources combined* (1.9 million tons), including INCO Limited in Sudbury.

**"Acid Rain", U.S. EPA Office of Research and Development, July 1980, Report number EPA 600 9-79-036

1980 RANKING OF STATES AND ONTARIO ACCORDING TO SO_2 EMISSIONS FROM POWER PLANTS.
SOURCE: U.S. DEPARTMENT OF ENERGY DATA AS COMPUTED BY ENVIRONMENT ONTARIO

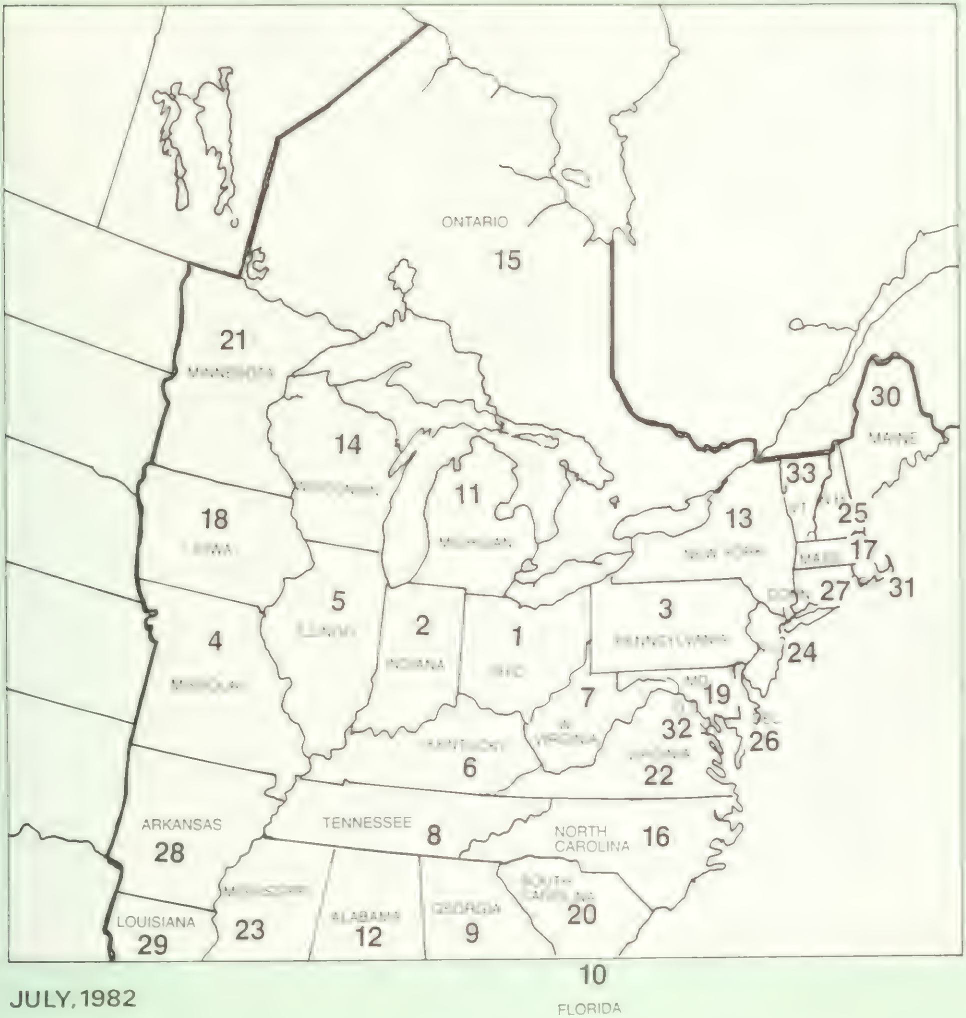
JULY 1982

TOP 50 COAL-FIRED POWER PLANTS IN EASTERN NORTH AMERICA RANKED ACCORDING TO TOTAL SO_2 EMISSIONS IN 1980*

RANK	PLANT	STATE	COUNTRY	ESTIMATED SO_2 EMISSION THOUSANDS OF METRIC TONS/YEAR
1	GAVIN	OHIO	USA	362.9
2	CUMBERLAND	TENNESSEE	USA	325.2
3	PARADISE	KENTUCKY	USA	314.5
4	GIBSON STATION	INDIANA	USA	275.3
5	CLIFTY CREEK	INDIANA	USA	261.4
6	BALDWIN	ILLINOIS	USA	235.2
7	BOWEN	GEORGIA	USA	227.6
8	MUSKINGUM	OHIO	USA	221.9
9	LABADIE	MISSOURI	USA	213.2
10	MONROE	MICHIGAN	USA	212.3
11	HARRISON	WEST VIRGINIA	USA	195.9
12	WANSLEY	GEORGIA	USA	191.9
13	CONESVILLE	OHIO	USA	189.0
14	KINCAID	ILLINOIS	USA	186.4
15	CONEMAUGH	PENNSYLVANIA	USA	186.1
16	KYGER CREEK	OHIO	USA	183.5
17	MADRID	MISSOURI	USA	180.9
18	HOMER CITY	PENNSYLVANIA	USA	167.3
19	HATFIELD	PENNSYLVANIA	USA	155.4
20	MITCHELL	WEST VIRGINIA	USA	154.8
21	GASTON	ALABAMA	USA	151.7
22	LAMBTON	ONTARIO	CANADA	150.0
23	MONTROSE	MISSOURI	USA	146.5
24	NANTICOKE	ONTARIO	CANADA	144.0
25	EASTLAKE	OHIO	USA	140.1
26	BIG BEND	FLORIDA	USA	139.6
27	COFFEEN	ILLINOIS	USA	139.2
28	KAMMER	WEST VIRGINIA	USA	135.6
29	KEYSTONE	PENNSYLVANIA	USA	129.1
30	BRUNNER ISLAND	PENNSYLVANIA	USA	126.1
31	GALLATIN	TENNESSEE	USA	124.3
32	SAMMIS	OHIO	USA	124.3
33	HILL	MISSOURI	USA	123.6
34	JOHNSONVILLE	TENNESSEE	USA	122.8
35	COLBERT	ALABAMA	USA	114.8
36	CARDINAL	OHIO	USA	112.5
37	CAYUGA	INDIANA	USA	104.7
38	STUART	OHIO	USA	103.3
39	MONTOUR	PENNSYLVANIA	USA	99.4
40	YATES	GEORGIA	USA	97.9
41	AMOS	WEST VIRGINIA	USA	95.4
42	PETERSBURG	INDIANA	USA	94.7
43	SHAWNEE	KENTUCKY	USA	94.0
44	JOPPA	ILLINOIS	USA	90.4
45	TANNERS CREEK	INDIANA	USA	90.1
46	FT. MARTIN	WEST VIRGINIA	USA	86.8
47	SIOUX	MISSOURI	USA	84.6
48	MILL CREEK	KENTUCKY	USA	84.4
49	MORGANTOWN	MARYLAND	USA	83.7
50	MT. STORM	WEST VIRGINIA	USA	83.3

*POWER PLANTS WERE CONSIDERED FROM ONTARIO AND 32 EASTERN U.S. STATES
THE STATISTICS ARE FROM ONTARIO HYDRO AND THE U.S. DEPARTMENT OF ENERGY;
THE ANALYSIS WAS PERFORMED BY THE ONTARIO MINISTRY OF ENVIRONMENT, AIR RESOURCES BRANCH

1980 ranking of states and Ontario according to SO_2 emissions from power plants.
Source: U.S. Department of Energy and data as computed by Environment Ontario.



JULY, 1982

Increased energy use entails bigger sulphur emissions*

The world-wide use of energy increased greatly during the period from the end of the Second World War up to the beginning of the 1970s. Oil became the predominant fuel input. Table 1 shows what the situation is like today (based on official statistics from 1978). The combustion of coal and oil accounts for close on four-fifths of the sulphur emissions in the world (Table 2) . . . .The rapid rise in energy costs that followed upon the oil crisis in 1973 will probably lead to more efficient energy use. . .Oil will slowly lose its dominant position and will be replaced by coal, gas, nuclear power and, in time, renewable sources of energy. Since sulphur is present only in coal and oil it is the future consumption of these fuels that has the most decisive bearing on the acidification of our environment.

The likelihood is that up to the end of this century the aggregate consumption of coal and oil will not alter enough to make any material difference to the sulphur emissions. Special measures are therefore called for on the discharge side if these emissions are to be reduced.

TABLE 1. Consumption of fossil fuels and other energy (nuclear, hydro, etc.) in various areas in 1978 Converted to corresponding quantity of oil = megatonne oil equivalents (M toe)

	Fuel consumption, M toe						
Area	Solid fuels	Liquid fuels	Gas	Total fossil fuels	Others	Total energy turn-over	toe per head
North-western Europe	183	383	143	709	76	785	4.3
Southern Europe	83	311	49	443	57	500	2.1
Eastern Europe	228	101	59	388	8	396	4.3
USSR	334	410	290	1034	111	1145	4.5
North America	378	956	499	1833	212	2045	8.5

TABLE 2. Emissions of sulphur dioxide in various areas in 1978, expressed in millions of tonnes of sulphur (Mton S) per year, kilograms of sulphur per tonne of fossil fuels (as oil) and grams of sulphur per megajoule of fossil fuels

	Sulphur emissions						
Area	Combustion Mton S/year	kg S per toe	g S/MJ	Industrial processes Mton S/year	Total sulphur emissions Mton S/year	kg S per head	Tonnes S per km^2
North-western Europe	5.3	7.5	0.18	1.1	6.4	35	3.2
Southern Europe	5.0	11.3	0.27	2.0	8.0	30	2.7
Eastern Europe	5.3	13.6	0.32	1.0	6.3	57	6.2
USSR	9.8	9.5	0.23	2.5	12.3	47	0.6
North America	12.3	6.7	0.16	3.9	16.2	67	0.8

Extract from "Acidification Today and Tomorrow", a Swedish study prepared for the 1982 Stockholm Conference on the Acidification of the Environment, Swedish Ministry of Agriculture. (page 208-9)

Atmospheric Studies

Environment Ontario atmospheric studies have shown that a large proportion of the precipitation in Ontario is generally associated with moist air masses that originate in the Gulf of Mexico. With transport over industrialized eastern United States, the air becomes laden with acid bearing compounds. Precipitation due to warm fronts and that from convective cloud associated with this air mass is acidic on arrival to the province. (see figure below)

Back trajectory analyses is a name given to a procedure by which air parcels are followed backward in time to determine the origin and track that the air parcels have taken. Data from precipitation collectors operated at Dorset in one of Ontario's sensitive areas (Muskoka-Haliburton) over almost a three year period (August 1976–April 1979), showed that about 75% of the precipitation events and moreover, approximately 80% of the wet acidic deposition at this site, were associated with air masses arriving from the south and southwest. Comparitively a small percentage of the loadings came from the north and northwest where major Ontario sources are located. It was also found that the acidity of precipitation related to southerly air masses was more than twice as great as that of precipitation from the north.

Figure of typical storm track across central United States into Ontario
Dotted areas represent precipitation associated with this typical storm track.

Appendix "A"

Three Environment Ontario reports concerning field analyses of precipitation (both rain and snow) falling in the Muskoka-Haliburton and Sudbury areas, released May 27, 1980.

1. **"Acidic Precipitation in South-Central Ontario: Analysis of Source Regions Using Air Parcel Trajectories".**

Based on field monitoring of rain and snow from 1976 to 1979, this study indicates that 90 per cent of the precipitation come from sources to the south of the Muskoka-Haliburton areas, and 10 per cent from sources to the north of these areas. Northerly sources account for roughly 9 per cent of the acid, 7 per cent of the sulphate and 8 per cent of nitrates. The sources to the south and southwest contribute 80 per cent of the acid, 75 per cent of the sulphate, and 65 per cent of the nitrate. The remaining 11 per cent acid, 18 per cent sulphate and 27 per cent nitrate come from the south-east.

2. **"Bulk Deposition in the Sudbury and Muskoka-Haliburton Areas of Ontario During the Shutdown of INCO Ltd. in Sudbury".**

This bulk deposition study compared measurements of all atmospheric fallout both wet and dry. Field studies were carried out both before and during the pro-longed nine-month shutdown of INCO Ltd.'s Sudbury operations in 1978. It was found that acid loadings to the lakes did not show any marked change in the Sudbury or Muskoka-Haliburton areas during the INCO shutdown. In effect, the conclusion drawn is that long-range transport of pollutants from a southerly direction has a major impact on the Muskoka-Haliburton area. The Sudbury smelter complex has a major effect on copper and nickel deposition close to Sudbury and minimal effect on acid loadings near Sudbury. Nevertheless, the acid loadings from the superstack no doubt have their effects on other parts of eastern Canada and the United States.

3. **"An Analysis of the Impact of INCO Emissions on Precipitation Quality in the Sudbury Area".**

This study confirms the contribution of INCO's summer season emissions to the total wet deposition in the Sudbury area, depending on the weather system passing through the area. For acids, sulphur and a number of trace metals, the INCO contribution in this area is about 10 per cent of the total during warm fronts, and twice that amount during cold fronts. About 40 per cent of copper and nickel deposition in the Sudbury area can be attributed to INCO Ltd. regardless of the weather.

Major Submissions by Ontario to the U.S. EPA and States

A Submission to the U.S. Environmental Protection Agency on Opposing Relaxation of SO_2 limits in State Implementation plans and urging enforcement. March 12, 1981. Expanded March 27, 1981. Toronto, Ontario: the Ministry of the Environment, 1981.

A Submission to the U.S. Environmental Protection Agency on Interstate Pollution Abatement: December 1981, Docket No. A-81-09. Ministry of the Environment (Ontario Government Bookstore, 880 Bay St. Toronto, M7A 1N8 — $15.00).

Presentation to the Air Pollution Control Board of the State of Indiana in Opposition to the Indiana-Kentucky Electric Generating Station Petition to Operate with an Increase in its Sulphur Dioxide Emissions to 7.52 pounds of SO_2 per million BTUs of heat input. Toronto, Ontario: Ministry of the Environment, 1981.

Presentation to the Michigan Air Pollution Control Commission in Opposition to the Detroit Edison request to delay bringing its Monroe power plant into compliance with the state of Michigan "1% of equivalent sulphur in fuel" rule. Monroe, Michigan. June 30, 1982. Toronto, Ontario: the Ministry of the Environment, 1982.

Ontario

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